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Devoted to the Advancement of Scientific Metallurgy

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Progress on the Problem of Transverse Fissures

DR. M. E. MCDONNELL

X-Ray Metallography in 1929

Part III

PROF. GEORGE L. CLARK

The Electrolytic Preparation of Alloys of Barium and of Strontium

KENNETH W. RAY

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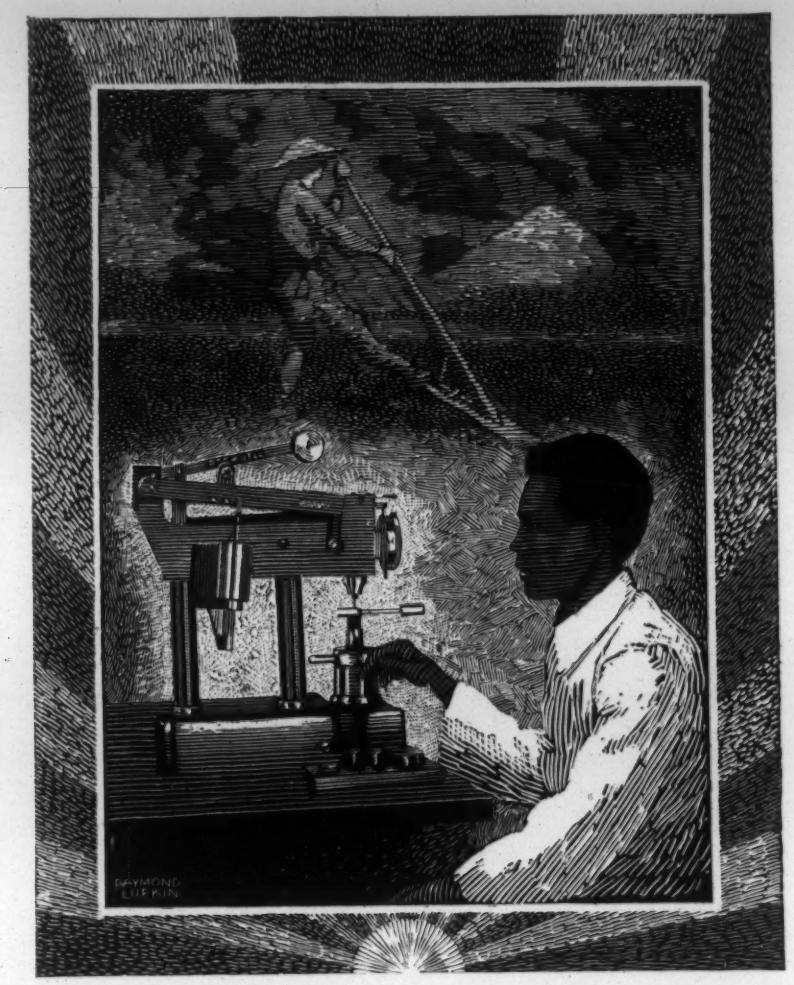

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Published Monthly by

THE CHEMICAL CATALOG COMPANY, INC.

Publication Office: 20th and Northampton Sts., Easton, Pa.
Editorial and Advertising Office: 419 Fourth Ave., New York

BRANCH OFFICES:
953 Leader Building, Cleveland
1050 Straus Building, Chicago
703 Market Street, San Francisco

Francis M. Turner, Jr., Pres. *L. F. Nellis, Vice-Pres.* *H. Burton Lowe, Vice-Pres.* *R. W. Reinhold, Secy.-Treas.*

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Annual Subscription: U. S., Possessions and Cuba, $3.00; Canada, $3.50; Other Countries, $4.00; Single copies, 40c.
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PUBLISHER'S PAGE

Note—On this page the publishers will talk right straight to you each month. We will tell you how things are progressing with METALS & ALLOYS. *We will undoubtedly ask your advice on many points. We are publishing this paper not primarily to please ourselves but rather to serve you. And our office door is always open. You are invited to call.*

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To sum the matter up, then, you can do two important things for us which we are quite unable to do for ourselves without your assistance. You can help us either directly or indirectly to secure new readers. You can strengthen the hands of our editors by telling them what *you* would like to see in forthcoming issues of the paper and by serving as a correspondent in the matter of news notes of interest to the field. We are told that METALS & ALLOYS has already made a good start. We firmly believe that with your assistance we can greatly improve the paper during the coming year.

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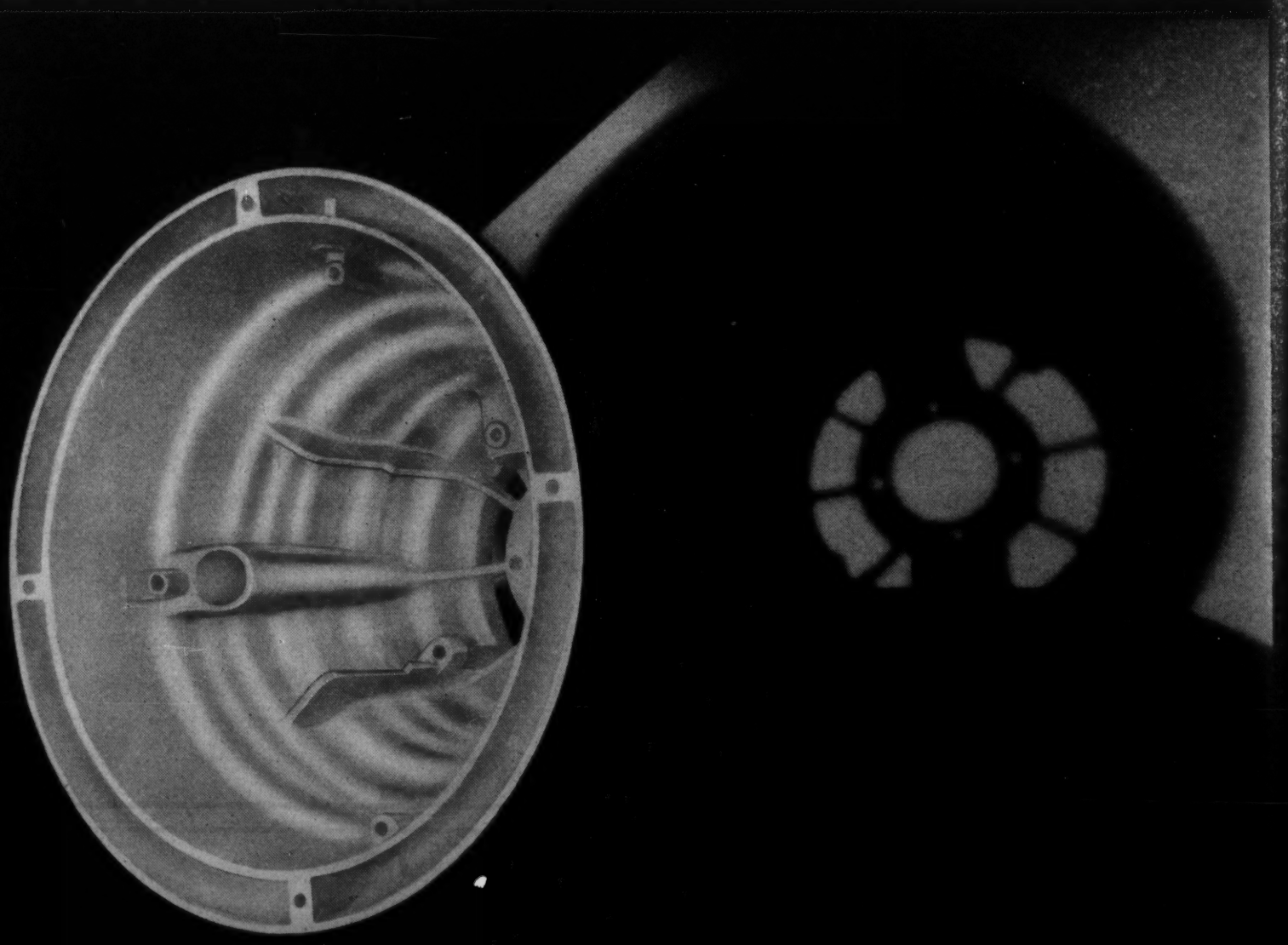

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Editorial Comment

In this department I try to comment on metallurgical and allied matters that seem to me interesting and significant. The views expressed reflect my own personal attitude. Many of our readers will have ideas of their own on these subjects and are urged to contribute them in the form of letters which will gladly be published in succeeding issues.—H. W. GILLETT, *Editorial Director.*

Possible New Tools for Scientific Metallurgy

The fact that the space lattice of a crystal acts as a diffraction grating for rays, such as X-rays, whose wave-length is of a suitable order of magnitude, has, in the last fifteen years, thrown a flood of light on the internal structure of crystals, especially of the metals. The chronology of physical metallurgy might well be divided into two epochs, one before and one after the advent of X-ray crystal analysis, more or less on the order of dates B. C. and A. D.

Were the X-ray evidence to stand by itself, its meaning might still be doubtful, but in so many regards it agrees with the crystallographic evidence obtained by the more cumbrous and less elegant methods of the old-time mineralogist that it has won ready acceptance.

Some thirty universities and pure science research organizations and some fifteen commercial research laboratories of the United States are using X-ray diffraction outfits, some of the groups having several, which is pretty good evidence that the data thereby obtained have an interpretable meaning of industrial importance.

With the X-ray so firmly established the question arises whether similar methods using other short wave-lengths might not give information that the X-rays do not give.

There is some ground for hope that beta-rays might be affected by the electron arrangement within the atoms, and from the theories of magnetism it is more or less evident that magnetic changes have something to do with electron arrangement. The old problem of what really happens at A_2 in iron is as mystifying as ever. Beta iron is hanging onto metallurgical consideration only by the skin of its teeth. In most modern theories of heat-treatment it plays no part. Yet the heat effect at A_2 is clamoring for an explanation. The X-rays tell us that there is no change in the crystal structure at A_2, whatever is going on is of a different type than an ordinary inversion. Magnetic studies show that the magnetic change is gradual, while the A_2 heat effect is sharp. If we knew what is really happening to the electron arrangement all these phenomena might snap into place in a complete theory.

Hence the idea that exploration of the A_2 change by means of a beta-ray spectrograph might possibly throw light on the electron arrangement is worth consideration, and the Bureau of Standards is working along that line. Since beta-ray technique is in its infancy many difficulties will have to be overcome before it can be told whether a new weapon is to be added to the metallurgist's arsenal or not.

The fact that a stream of electrons is diffracted by the space lattice of a metal, much as X-rays are, was recently discovered by the Bell Telephone laboratories. This discovery is a double-barreled affair, with vast possibilities for further explanation of the nature of the electrons in the stream, of interest to physicists, and with even greater possibilities to the metallurgist.

The electron stream is less penetrating than X-rays of the same wave-length and appears to tell much more about what occurs at the surface of the metal than do X-rays. Germer[1] has studied a single crystal of nickel upon which a stream of electrons impinges in vacuo. He finds that with an extremely perfect vacuum and a clean metal surface, the diffraction pattern is that of the nickel lattice. In a slightly less perfect vacuum, some gas, whose identity is not known, forms a partial layer over the metal, but the gas atoms do not entirely cover the surface, they are stuck on, something like cloves in a baked ham, and leave unshielded just one-quarter of the nickel surface. They are not attached in helter-skelter fashion, but are regularly arranged, just as regularly as the atoms of the nickel crystal itself—indeed, each gas atom is directly over the third underlying layer of nickel atoms. The fields of force emanating from the nickel atoms make the gas atoms become adsorbed in definite locations, so that we have the first layer of a "gas crystal." If the gas atoms settle on the crystal at a temperature above 150° C., they do not take up this regular arrangement since the force field is weaker at higher temperatures. In a poorer vacuum a thicker, multi-molecular gas layer collects which does not appear to be so regularly oriented at a greater distance from the crystal, where the force fields die out.

Any metallurgist reading this paper of Germer's will at once emulate Oliver Twist and ask for more. A method of attack that tells so much about the surface conditions may well offer a means of getting *direct* evidence on the existence or non-existence of the alleged "amorphous layer" sometimes said to be formed on polishing, but nowadays more generally held to be a layer of very tiny fragmented crystals or crystal parts, not amorphous. Germer's nickel crystal was a single crystal, cleaned by etching and it should, of course, have no amorphous layer after that treatment. The evidence is so good that the surface is perfectly oriented that it would appear very likely that the same method of study of polished surfaces would give equally definite and interpretable data, provided that the method can be applied to polycrystalline material as well as to single crystals. Whether this turns out to be the case or whether the application is limited to single crystals, it is evident that a powerful weapon is at hand for attack on the problems concerning metal surfaces and the force fields of the atoms in the space lattice.

Will we soon find beta-ray spectrographs and electron spectrographs in as common use as X-ray spectrographs, and all of them ultimately considered as necessary a part of the metallurgist's outfit as the microscope and the pyrometer are today?

[1] L. H. Germer, "An Application of Electron Diffraction to the Study of Gas Adsorption," *Bell System Tech. Jour.*, **8**, 591–604 (1929).

German in Metallurgical Courses

We suspect that one reason why the average metallurgist is lukewarm to the agitation for the metric system, despite his recognition that it would be superior if we could start from scratch, is that the minor irritation of conversion from metric to English units or the reverse is nothing compared to the major irritation of translation from German to English. No metallurgist worthy of the name can ignore the work of the Germans. He has to take it into account sooner or later and either at first-hand or at second-hand. While copious abstracting and some direct translation, such as will be given in METALS & ALLOYS, will help, yet every one engaged in metallurgical research is sometime confronted with the necessity of either reading himself, or having translated so he can read them, some of the original articles in German.

Too many of us, and the writer is in that category, read German with a dictionary, much perspiration, and much profanity anent the Tower of Babel. It would save time in the long run and vastly improve the quality of the crop of young metallurgists being grown by our technical schools if a reasonable reading knowledge of scientific German were required of students in metallurgy, not only for advanced degrees, but in the four-year courses. Perhaps the schools of metallurgy have mended their ways recently, but in considering applications from graduates of the last ten years, it appears that far too many schools have not included German in the curriculum in that period. Ability to struggle along with a French paper is not uncommon, but ability to handle German even with difficulty is not common.

But if any reader will jot down the names of the twenty men he considers the leaders in scientific metallurgy in the United States to-day, he will find, we predict, that fifteen of them handle German readily and the rest, much as they hate to do it, can read it in a pinch. The youngster who aspires, as he grows older, to join this group should take notice and his instructors should frame the curriculum so he has to take scientific German in college.

There is no other way out. Swedish and Japanese metallurgists are kind enough to publish most of their important works in English; Russian and Italian work in metallurgy is still so limited that not much is lost by having to get a special translation made when we must have all the details of such work. But the situation as to German is not to be handled in this way. We suspect that if the German metallurgists realized how much more recognition their work would get in America if they published in English they might do so to a certain extent, but since so many of them read English they do not know how few Americans read German. At any rate they seem satisfied with their present circle of readers, which includes even the immature metallurgists in all progressive countries save America. So the only remedy lies in the hands of the metallurgical schools. No one can blame a youngster for avoiding German in his college course if he can graduate without it. It is a horrible language for the average American to try to learn, especially if he goes at it too late in life. But our college professors ought to know when to make the students do what is good for them whether they like it or not.

This will require cooperation from the German departments of the universities, for what is needed is a special course in scientific German, not merely one in German literature. It should be a B.S. course, not an A.B. course.

Cost of Specimens as a Factor in Fatigue Testing

In spite of all efforts toward accelerating the process of fatigue testing, there is, so far, no certain short cut. Several specimens must be tested, some at stresses that cause fracture and one or more at stresses that leave the specimen unbroken after, say, 10 million cycles for steel. For aluminum and other non-ferrous materials it may be necessary to go to 500 million or more.

Confining our discussion to steel, we may calculate roughly that an average of six specimens and a period of about ten days are required to give a fairly reliable figure for endurance limit on a single steel, at the usual speed at which the fatigue machines run. One endurance machine in steady use will then test about 36 lots of steel per year and use something over 200 specimens.

The machine most in use, the R. R. Moore machine for short specimens, without base, costs about $400.00. We venture to estimate that by the time a specimen has been machined and polished ready for test it will have cost the average laboratory at least $3.00 for its preparation, often more. That is, in a year, specimens will cost about $600.00, or more than the machine itself. Specimens for other types of machines may not be quite so costly, but at any rate they are a heavy expense.

It is time some one took up the study of fatigue testing from the point of view of reducing the cost of machining the specimen. This might take the path of working out quantity production methods of machining or grinding specimens for present machines, remembering that if the final tool marks or grinding marks are longitudinal instead of transverse, much less final polishing will be required to put the specimen into proper condition for testing. Or it might take the path of designing a machine which, besides running at as high a speed as is compatible with accurate measurement of stress, will handle a specimen that can be cheaply machined and polished.

Two types of machines are needed, one for the usual rotating test of a bar of circular cross-section, the other for flexural test of sheet and other flat stock. The latter is probably the simpler from the point of view of a low-cost specimen, but the former is the one most used, since the bulk of the material to be tested is not flat stock.

If a machine could be devised which would take a cylindrical bar, it would not be difficult to prepare specimens cheaply by centerless grinding and mechanical polishing. But since the bars have to be necked down to avoid stress concentration and permit calculation of true stresses, it will be necessary to compromise on a necked bar that can be cheaply prepared and a machine that will handle that bar.

There will ultimately be a demand for "proof-tests" in fatigue as a routine procedure, even if complete determination of the endurance limit by testing several bars is left to the research laboratory.

One can economically pay more for a testing machine, or pay for special equipment for machining, if, in the long run, the cost of testing machine plus machining equipment plus machining and polishing labor for, say, a year's supply of test bars is less than the present cost of those items.

The firms whose research laboratories are engaged in endurance testing programs and which also have modern machine shops and qualified designers of machinery could do the metallurgical fraternity a service by getting their various departments to consider the problem of lowering the ultimate cost of fatigue testing.

Progress on the Problem of Transverse Fissures in Rails

By M. E. McDonnell*

Transverse fissures in rails were brought into prominent attention 18 years ago by a wreck near Manchester, N. Y., in which 29 people were killed and 62 injured. The wreck was due to failure of a rail from a transverse fissure. A transverse fissure is a crack, starting in the interior of the head of a rail without showing any sign on the outside, which grows larger through repeated loading under the wheel-loads imposed on the rail. It lies in a plane at right angles to the length of the rail. (Figure 1)

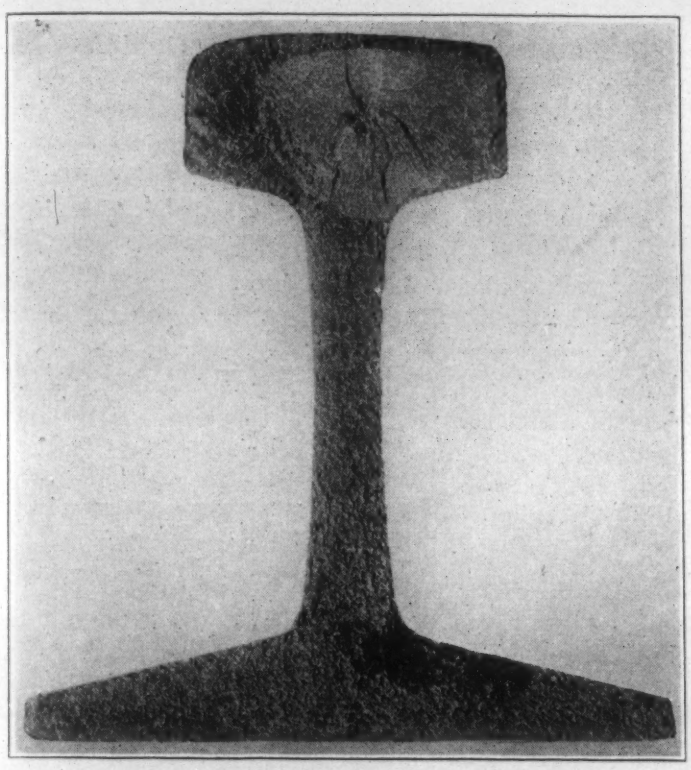


Figure 1—A Typical Transverse Fissure. (Courtesy Bureau of Standards)

The continued flexing of the rail causes the faces of the fissure to rub together, so that upon final fracture of the rail the previous existence and extent of the fissure is shown by an oval spot surrounding the nucleus of the fissure. The growth of a transverse fissure is admitted by all to be a fatigue failure.

Since no method of visual inspection will detect the fissure, and since when rails containing fissures do fail, they fail without warning, they are a constant source of apprehension to the railroads. The elimination of fissured rails from track is a matter of public interest.

In 1914 rail failures from all causes in the United States and Canada were about 80 per 100 track miles; in 1924 the rail failures rose to 100 per 100 track miles. Of these failures perhaps 15% on different roads, of heavy traffic, are due to transverse fissures. Rail breakage of any sort is rare on the light-traffic roads. While the potential danger from transverse fissured rails is great, the actual number of failures is small, only one rail in about every 1500 or more in use ever failing from this cause. Only about one heat of rail steel in 50 produces one or more rails failing by transverse fissure. Detecting the primary source of the transverse fissure is something like looking for a needle in a haystack.

* Chief Chemist, Pennsylvania Railroad, Altoona, Pa.

Although it often happens that, on breaking up a fissured rail after removing it from the track, no other transverse fissure is found, yet it is the custom among many railroads to remove from the track all rails of the heat from which the failed rails came, after three fissured rails are found from that heat. Every rail is marked with its heat number, ingot number and position in the ingot, to facilitate such removal and to allow compiling statistics on rail failures. There seems to be a slight tendency for fissures to be more prevalent in certain heats than in others, and to occur in the rails from the top of the ingot.

Removing the balance of the heat is a safety measure, but a drastic one, and it takes out many perfectly good rails. This safety measure must wait for one rail to "detect itself" by actual failure.

A vast amount of work has been put on the problem by railroads, individually and through the American Railway Engineering Association, by rail makers and by government organizations. Many theories have been advanced as to the primary source of fissures. Some of these theories are conflicting. One group, whose opinions are voiced by Mr. J. E. Howard, Engineer Physicist of the Interstate Commerce Commission, holds that the wheel loads of to-day are excessive, setting up both external and internal stresses, the latter by the cold-working of the head of the rail by the rolling action of the wheel, which stresses are taken to be above the endurance limit of the soundest present-day rail steel, even in the heaviest rails, and that therefore the fissure develops in service, but not from a pre-existent nucleus. This throws the onus on the railroads and leaves the rail makers scot-free.

There has in the past perhaps been some tendency on the part of the rail makers to be willing to leave the responsibility solely in the lap of the railroads, with the argument that the rail makers meet specifications which are set up by the railroads and that if and when the railroads want rails of different properties, they should alter the specifications.

The other group feels that, were the wheel loads really in excess of what sound present-day rails will bear without development of a transverse fissure, all rails in similar service would show transverse fissures and would fail after similar periods of service, each rail failing in many places all at once, like the "one-hoss shay." Since rails do not fail in such an orderly fashion, but may develop a transverse failure after only one night in the track (in the most striking case) and often after only a few months, while others apparently in as severe service withstand traffic without trace of fissure for many years, being finally removed for wear, the second group postulates a pre-existent nucleus, present in some rails as they leave the mill, but not present in all, as primary source of fissures.

In this case, whether or not the railroads know how to specify or to test so as to avoid acceptance of rails destined to fail by fissures, the possibility exists that some variable in mill practice, when located and put under control, may be the means of preventing transverse fissures *at the source*.

Unless fissures can either be avoided by eliminating the cause or causes, or can be detected and rejected before they leave the mill or at least detected in the track and removed from it before they are due to fail, there is only one answer to the problem, that of reducing the severity of service by reduc-

ing the wheel loads and speeds. From the economic point of view a return to the light loads of many years ago when service was so much less severe than at present and transverse fissures were practically unknown is almost unthinkable. A solution of the problem which brings the properties and the uniformity of the rail up to the point where it is fully and certainly able to cope with present-day conditions, with a margin for withstanding even more severe service in the future, is devoutly to be hoped for.

The old jealousies between rail maker and rail user are fading away and active cooperation is the rule to-day. The problem is complicated by the fact that rails are a tonnage product and, in actual cold blood, it is cheaper to take the risk of an occasional train wreck than to pay excessive prices for fissure-free rails. Any remedy can be a real solution only when it can be applied to large scale tonnage rail production. It might be possible to make a superior rail of an alloy of platinum and iridium, but, even if it were, it would not help matters.

In the early days of the study of transverse fissures, much attention was concentrated on the chemical analysis of the steel in the hope of being able to set up a specification for chemical analysis that would eliminate rails destined to fail. This has not been found possible and chemical specifications have remained practically the same for many years. Neither do the ordinary methods of mechanical testing, tensile, drop and "nick and break" tests offer any security in differentiating between good rails and rails that will fail. Rails that pass all these chemical and mechanical tests and are free from notable segregation continue to fail by transverse fissures, year after year.

In recent years attention has been paid to the question of the endurance or "fatigue" properties of the rail, since it is certain that a transverse fissure is a fatigue failure.

In choosing a metal to withstand repeated stress the engineer asks two questions. What stresses will be applied in service? What is the engineering endurance limit of the metal under stresses of the nature that will be applied in service? He uses the term "engineering" endurance limit because he is not primarily interested in the best figures that metal can show, but rather in the lowest figure the poorest specimen of the metal will show, in the condition in which it is delivered to him ready for use.

Exact answers to either question are not yet forthcoming. The stresses in track are highly complex and hard to measure. The problem is complicated by the presence of internal stresses both present before service and produced in service, whose magnitude it is hard to measure exactly, and which cannot even be guessed at by any non-destructive method. Track stress measurements indicate[1] that the usual load at the base of the rail in well maintained track run around 15,000 lbs./sq. in. but that in rare cases they may rise to the order of 75,000 lbs./sq. in.

The engineering endurance limit of ordinary rail steel, determined in rotary bending, i. e., with equal tension and compression stresses, seems to run between 40,000 and 60,000 lbs./sq. in. If these figures were directly comparable it would appear that in the rare cases of high track stress the endurance limit may be exceeded, and transverse fissures might be laid to stress alone.

But the important fact arises that the nucleus of a transverse fissure is not at the base of the rail where the bending stress is highest, but is, instead, in the head of the rail, and well below the surface. Moreover, the endurance limits are not simply 40,000 to 60,000 lbs./sq. in., they are ±40,000 to ±60,000, i. e., a stress range of 80,000 to 120,000. Since the maximum stress range at the base of the rail is not from 75,000 lbs./sq. in. in tension to the same figure in compression, but from that figure in tension to a much lower figure in compression, the total stress range on the rail, even in the worst cases, is probably not above the calculated stress range for the rail steel of lowest endurance limit. Moreover the relationship between the stress range in completely reversed loading, as in the usual rotary beam endurance test, and the stress range of slight compression to high tension is only hazily understood.

Leaving the question of endurance, to return to it later, we may consider some of the suggestions for prevention and detection of fissures.

It was noted above that there was some indication that the top or A and B rails from an ingot are slightly more prone to fissures than the rails from positions farther down in the ingot. For this reason, and because experience with high grade alloy steels has amply demonstrated that better steel can be gotten by the use of a "big-end-up, hot-top" ingot instead of the small-end-up ingot commonly used for rail steel, there has been considerable study[2] of rail steel from the former type of ingot.

While no very radical improvement is shown in average properties on laboratory tests, results on the basis of some service tests do indicate improvement. Cushing claims[3] a two-thirds reduction in fractures in rails from big-end-up ingot. It is obvious, however, that big-end-up hot-top rails are not by themselves alone an entirely adequate answer to the problem though they may well prove to be an important factor in the final answer.

A promising method of attack, not as a preventive of the production of rails liable to failure, but as a means of detecting them in track before failure has progressed far, is the new Sperry rail "Flaw Detector," whose advent has been heralded as marking an epoch in the history of the transverse fissure problem. Not only is it alleged to be a direct means to safety, by making possible the prompt removal of the rails, it points out as on the way to failure, but it is also an economic factor through allowing the retention in track of good rails from the same heat as a fissured rail. Moreover, if successful, it should allow much more rapid collection of data and statistical study than would be the case were it necessary to wait for the fissured rail to report itself by actual failure.

Previous attempts to detect an internal fissure by magnetic means[4] were unsuccessful in spite of long and careful work. Recently Suzuki[5] of the Japanese Government Railways has described a magnetic method, but its success cannot yet be considered as substantiated.

There seems to be no question but that Sperry's method[6] has been successful in detecting some fissures in track before they grow large enough so that failure impends. It also appears that it will not show up the so-called "shatter cracks."

The detector car carries a generator which supplies a high amperage direct current through brushes to each rail. Large cracks, fissures or other discontinuities alter the distribution of current over the cross-section of the rail. A secondary coil near the rail is affected by this change of flux, and by

[1] W. C. Cushing, *Rail and Wheel*, **30**, *Bull.* **315**, Am. Ry. Eng. Assn., March, 1929, page 211.

[2] E. F. Kenney, "The Commercial Production of Sound and Homogeneous Steel," Yearbook, Am. Iron and Steel Inst., **1915**, page 144. G. K. Burgess, "Steel Rails Sink Head and Ordinary Rail Ingots," Bureau of Standards, *Tech. Paper* **178**, 1920. R. A. Hadfield and G. K. Burgess, "Sound Steel Ingots and Rails," *Jour. Iron and Steel Inst.*, **91**, 40 (1915), No. II; *Trans. Am. Inst. Min. Eng.*, **51**, 862 (1915). J. R. Freeman, Jr., R. L. Dowdell and W. J. Berry, "Endurance and Other Properties of Rail Steel," Bureau of Standards, *Tech. Paper* **363**, 1928.

[3] W. C. Cushing, work cited, reference 1.

[4] R. L. Sanford, "Location of Flaws in Rifle-barrel Steel by Magnetic Analyses," Bureau of Standards, *Sci. Paper* **343**, 1919.

[5] M. Suzuki, "On a New Magnetic Rail Defectoscope," Tohoku Imperial University, *Sci. Report* **15**, 479 (1926).

[6] "Committee Report—Transverse Fissure Detecting Device," *Trans. Am. Ry. Eng. Assn.*, **28**, 966 (1927). E. A. Sperry, "Non-Destructive Detection of Flaws," *Iron Age*, **122**, 1214 (1928).

radio amplification methods the change of flux actuates recording pens to produce a record. A sufficient change to indicate a fissure or other dangerous flaw actuates a paint gun which deposits a shot of red paint on the rail at the point in question.

The method as applied in the laboratory is considered to be of sufficient sensitivity to detect flaws of 1 to 2% of the cross-sectional area of the rail. This sensitivity is too low to detect shatter cracks. Hence, if shatter cracks are nuclei for fissures, they cannot be detected at the rail mill. The rail must be put in service and the fissure allowed to develop to a size which the detectoscope will pick out.

There is still some question whether the detector car is as reliable in its indications as the method seems to be when applied in the laboratory.

In a six-day run on one railroad, about 100 rails were indicated by the detector car to be defective. On breaking these rails under the drop it was found that the majority did not have internal transverse fissures, but that many had been "burnt" by slipping drivers or showed slight crushing of the head, neither cause being sufficient to impair further serviceability of the rail.

On the other hand, some of the rails did show, when broken up, internal transverse fissures an inch or more in diameter, that had not been indicated by the detector car. Without further improvement in the equipment of the car beyond its stage of development at the time of this test run, the railroad doubts whether the car will serve a useful purpose, but hopes it will ultimately be developed to give reliable indications.

In a summary of the transverse fissure situation up to 1926, the Rail Committee[7] of the American Railway Engineering Association stated: "The Rail Committee has reason to believe that the shattering crack is the nucleus of the transverse fissure and that without its pre-existence no detail fatigue failure has ever been developed from the interior zone in the rail head admittedly stressed by service conditions. The real crux of this problem does not lie in the impinging pressure of the wheel upon the head of the rail, but rather lies in determining the cause of the shattering crack at the steel mill. When the cause is determined its elimination may be reasonably expected."

Emerson[8] states: "To the best of our knowledge no rail in which a transverse fissure has developed to the point of rupture has ever failed, when thoroughly examined for shattering cracks, to exhibit their presence in the zone of transverse fissure nuclei, and exhaustive search in the same zone in the heads of rails in track from heats which have not developed fissures fails to find the shattered structure."

Two independent investigations, approached from entirely different angles, have recently been recorded, the results of which tend to substantiate this statement. An exhaustive study by the Pennsylvania Railroad, reported by Cushing,[9] deals with the metallographic examination of many sound and many fissured rails taken from track. Transverse shatter cracks were found in all fissured rails. Figure 2 shows the cracks in a rail that failed by transverse fissure after only one night in track.

Cushing concludes that "all transverse fissures have been *developed* in the track by the impinging wheel loads of the rolling-stock from defects *already existing* in the new rails as they have been received from the mills. The most frequent source of a transverse fissure is the shattered interior condition of the metal of the "head."

[7] G. L. Moore, Chairman Rail Committee, "Transverse Fissures," *Rail Report No.* **92**, Am. Ry. Eng. Assn., Feb. 1926, page 10.

[8] J. B. Emerson, Engineer of Tests, Rail Committee, Am. Ry. Assn. private communication, March 5, 1926.

[9] W. C. Cushing, "Rail and Wheel, Part III, The Genesis of the Transverse Fissure," Vol. 30, *Bull.* **315**, Am. Ry. Eng. Assn., March, 1929, page 227.

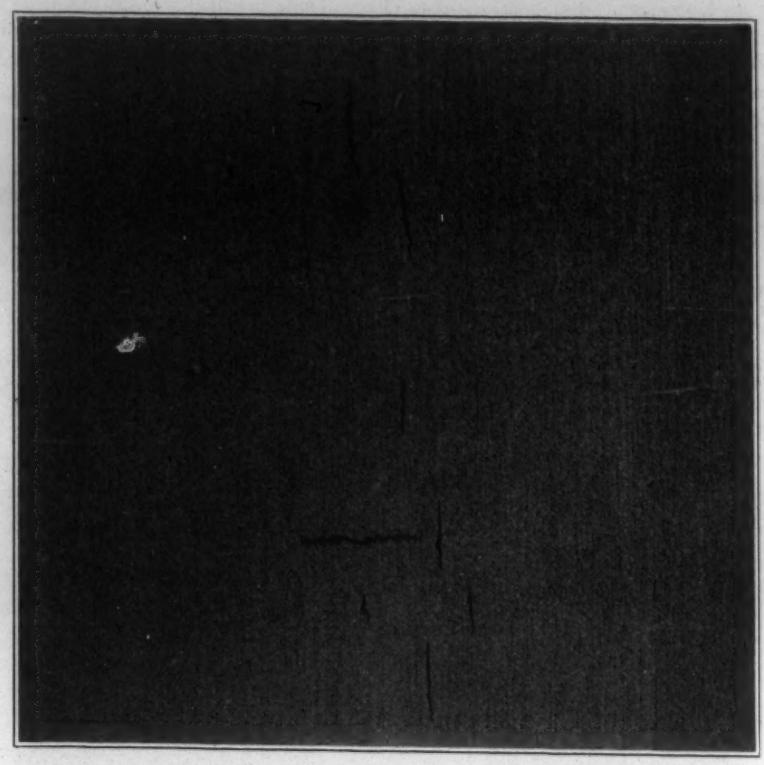


Figure 2—Shatter Cracks in 130 Lb. Rail Which Failed by Transverse Fissure Starting from the Shattered Zone. This Rail Was in Track Only One Night before Failure. (Courtesy Pennsylvania Railroad)

A study of steel from used rails made by the Bureau of Standards[10] leads, through evidence from endurance tests as well as from metallographic evidence, to practically identical conclusions.

The endurance properties of steel from new, unused, rails had been previously studied.[11] Rails from the same heats were subjected to over 20,000,000 tons of traffic on the Baltimore and Ohio Railroad, and the endurance properties of the steel from these used rails then determined.

No decrease in the endurance properties was found. The fatigue-resistance of the steel had not been damaged by service and the obvious conclusion is that the wheel loads were not above the engineering endurance limit of the steel.

These rails were free from shatter cracks and there was no sign that any nuclei for development of transverse fissures were created by service.

Another lot of rails, subjected to some 12,000,000 tons of traffic on the Canadian Pacific Railway, were similarly examined. While no marked deterioration had taken place and no transverse fissures were found in the rails examined, yet on the whole the endurance properties were on the average not so good as in the rails before service. The endurance results showed a marked "scatter" and a few very early failures of specimens in the endurance testing machine were met which were definitely associated with shatter cracks.

Early failure of a fatigue test specimen from a new rail of this lot was also found to be definitely associated with an internal crack.

It was evident that the shatter cracks in the new rail formed nuclei that might, under suitable conditions of repeated loading, cause fatigue failure that would not occur under the same conditions of loading were the cracks not present. Both Cushing and Freeman thus agree with Moore and Kommers[12] who say "Transverse fissures seem to develop from some defect which is initially in the rail and which acts as the nucleus of a fatigue failure."

[10] J. R. Freeman, Jr., and H. N. Solakian, "Effect of Service on Endurance Properties of Rail Steels," to be published soon in *Bureau of Standards Journal of Research;* see also Bureau of Standards, *Tech. News Bull.* **144**, April, 1929, page 32.

[11] J. R. Freeman, Jr., R. L. Dowdell and W. J. Berry, work cited, reference 2.

[12] H. F. Moore and J. B. Kommers, "The Fatigue of Metals," **1927**, page 240.

Two rails, neither one from the lots mentioned above, that had failed in track from transverse fissures were also examined by Freeman. With one of these there was also studied an adjacent unfissured rail which had been made by the same mill and subjected to the same traffic conditions on the Canadian National Railway. Of these two sister rails, the fissured one showed no other fissures and the unfissured one no fissures that were detectable when tested by the Sperry Flaw Detector. But the fissured one contained shatter cracks, while the unfissured one did not.

The endurance limit of the fissured rail was about ±57,000 lbs./sq. in. while that of the unfissured rail was only about ±45,000 lbs./sq. in. The other fissured rail, with which no sister unfissured rail was available for test, had the highest endurance limit, ±67,500 lbs./sq. in., of any of the rails so far studied at the Bureau of Standards, and it also showed shatter cracks. (Figure 3)

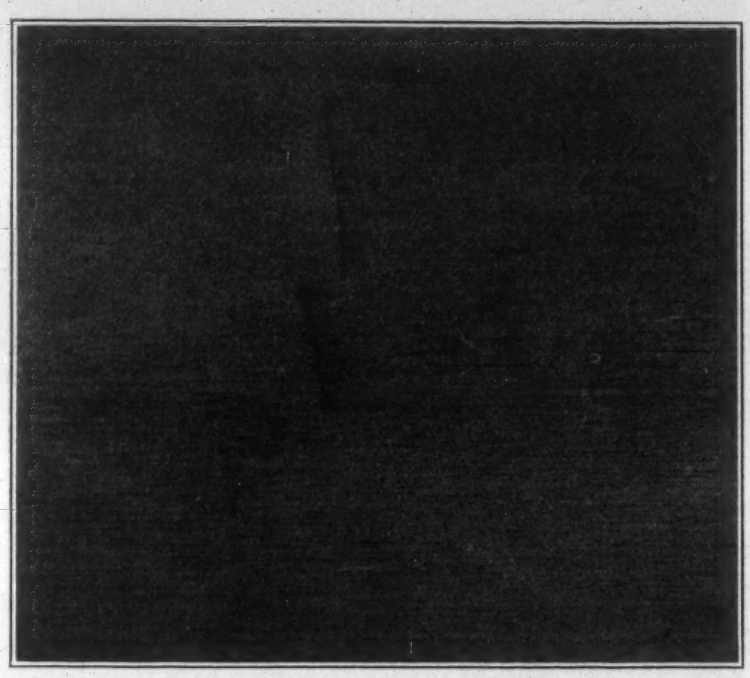


Figure 3—Transverse Shatter Cracks in a Rail That Showed, in Portions Free from Shatter Cracks, the High Endurance Limit of 67,500 Lbs./Sq. In. Yet Failed in Track by Transverse Fissure after Five Months' Service. (Courtesy Bureau of Standards)

It seems evident that a rail with an endurance limit on the low end of the range of values shown by present-day rails and free from shatter cracks, is safer than one with a high endurance limit but containing shatter cracks. What must be sought is rails with high endurance limits and at the same time free from shatter cracks or other "stress-raisers" that may act as nuclei for fissures.

According to Cushing[13] the presence of shatter cracks is not detected by the usual proof tests, but if the drop test is made with the rail head down instead of up, a peculiar star-like spot is found in the fracture of a rail with a shattered zone, the center of the star being located in the defective area. If this be substantiated and if the star fracture is readily recognizable by inspectors after reasonable experience, another step toward the elimination of transverse fissures in track can be taken by testing head down.

This testing method and the Sperry Flaw Detector, however, serve only to show and not to prevent shatter cracks and fissures. Effort is of course being put on the production of rails of higher endurance limit and with freedom from shatter cracks.

One way in which this is being sought is by alloying, especially by the use of the so-called "medium manganese" rail steel with manganese from 1.20 to 1.50 or even 1.70%, the carbon being carefully reduced to 0.65 or 0.60% as the manganese is increased, to avoid brittleness. The tensile strength is thus increased. Such data as have so far been published[14] do not indicate much improvement over the endurance figures for ordinary rail steel. Thum[15] cites Ray as stating that medium manganese rail is not expected to be immune from detailed fractures starting from internal nuclei.

Another method for increasing the strength is by heat-treatment. The Sandberg air-blast process of toughening the rail head is used to some extent abroad, but experience with Sandberg rails under American operating conditions seems to be lacking. Extensive trials are being made[16] of rails heat-treated by quenching the head in water for 30 seconds, then transferring at once to a tempering furnace. This raises the tensile strength of an ordinary carbon steel rail to 160,000 lbs./sq. in. or better. It is assumed[17] that the engineering endurance limit is proportionately raised.

It should be pointed out that this will only be true in case the steel is free from "stress-raisers." Freeman's tests of fissured rails show that a high tensile strength or high average endurance limit, without reference to flaws or to scatter in endurance testing, may give an entirely false sense of security.

Those who are developing the alloy steels and the heat-treated steels might well include exhaustive endurance testing in their research program.

It has been well said that "consistent mediocrity is better than intermittent perfection." If the real cause of shatter cracks can be found and eliminated in non-heat-treated carbon steel, the problem would apparently be solved for present wheel loads. If, then, the shatter cracks may also be avoided in steels of higher endurance limit, leeway may be provided for even higher wheel loads of the future.

There are signs that the attack on shatter cracks being made by slowing up the rate of cooling on the hot beds as suggested by Hibbard[18] more than a decade ago, and again by Cushing[19] may be fruitful. Cushing mentions often[20] that the source of the defect appears to be a thermal one.

Freeman found some indication that shatter cracks may be intercrystalline, i. e., formed at high temperatures. In his work at the Bureau of Standards, he has found[21] that some rail steels, tested at elevated temperatures, show a range of temperature in which strength and ductility are both low. This range of "secondary brittleness" varies in position, and in the degree of brittleness, in different steels. Room-temperature tests give no inkling of this, so that steels varying widely in high-temperature brittleness meet present specifications equally well. This work is still in progress and details have not yet been published.

These observations lead at once to the question whether or not the shatter cracks occur during cooling when the outside of the rail is relatively strong, but when the inside of the head, which is hotter, is in the range of "secondary brittleness." If they do occur then, the obvious next steps are to slow down the rate of cooling, as a practical preventive of cracks and to try to search out the factors which make one heat more prone to cracking than another, so that prevention may ultimately be applied at the real source of the trouble.

At the Metallurgical Advisory Committee meeting early in May, the Bureau of Standards expressed the hope that

[13] W. C. Cushing, work cited, reference 1, page 273.

[14] R. I. Scholes, "Report of Sub-Committee on Tests of Alloy Steel," vol. 30, *Bull*, **315**, Am. Ry. Eng. Assn., March, 1929, page 1308.

[15] E. E. Thum, "High Strength Structural Steels," *Iron Age*, **123**, 797 (1929); "Medium Manganese Rail a Success," *Iron Age*, **123**, 940 (1929).

[16] W. C. Cushing, work cited, reference 1, pages 82 and 226.

[17] W. C. Cushing, work cited, reference 1, pages 207 and 213.

[18] H. D. Hibbard, Discussion, *Trans. Am. Inst. Min. & Met. Eng.*, **58**, 610 (1916).

[19] W. C. Cushing, work cited, reference 1, page 294.

[20] W. C. Cushing, work cited, reference 1, pages 66, 92, 213 and 294.

[21] Standards Yearbook, 1929, U. S. Dept. of Commerce, page 207.

some rail maker would experiment with slow cooling, and provide rails cooled at different rates to be examined for shatter cracks. It is very interesting that in the latter part of May Mr. C. P. Sandberg, whose experience in rail metallurgy makes his opinions carry weight, came to this country to try to interest rail makers and users in a method and apparatus for slowing down the rate of cooling on the hot bed after the rail has passed through A_1 but while it is cooling through the range of "secondary brittleness."

Quite independently, but following the same course of reasoning, he had come to the same tentative conclusions as had the workers at the Bureau of Standards. He states that rails thus slow-cooled appear to be free from shatter cracks, and are, so far, standing up well in service abroad.

It would seem thoroughly worth while for the scheme to be given a trial, and slow-cooled rails to be put into severe service in track under American conditions. The method should not be prohibitively expensive.

More information is needed on the properties of rail steel at high temperatures, to give an insight into what may happen on the cooling bed, as well as on the endurance properties at ordinary temperatures of medium manganese and heat-treated carbon rail steels, and on the relation between endurance limits determined in rotary bending and by repeated tension and compression in various ranges of axial loading. Work on these problems is in progress at the Bureau of Standards.

More data on the actual magnitude of wheel loads is also needed, and work on this point, as well as on other phases of the fissure problem, is in progress at the University of Illinois, while the Committee on Stresses in Track of the American Railway Engineering Association is also continuing its work. Constant effort is also being put on the improvement of the road bed so as to reduce track stresses.

The outstanding points in progress on the problem of transverse fissures in recent years seem to be:

1. The railroads and the rail makers are actively cooperating in attacking the problem.
2. Evidence seems conclusive that nuclei for transverse fissures may exist in new rails, i. e., it is not merely a wheel-load problem but a metallurgical problem as well.
3. The Sperry Flaw Detector and the head-down method of drop testing promise to be of service in detecting fissures and shatter cracks, respectively, thus giving some hope of making it possible to remove dangerous rails from track or to keep from putting them into track.
4. There is some evidence that the use of hot-top big-end-up ingot molds may be a desirable step toward dependable rail steel.
5. Efforts are being made to produce alloy or heat-treated rails of higher endurance limits and free from shatter cracks. More information is needed before this can be done with certainty, but active efforts are being put forth to produce this information.
6. Slow cooling of rails on the hot bed after passing through A_1 offers a possible means of preventing shatter cracks in the heat of steel prone to produce those cracks.
7. With the continued cooperation of all interests concerned the problem should ultimately be capable of solution.

To Head Electrochemists' Convention, Pittsburgh

Dr. Francis C. Frary Director of Research, Aluminum Company of America, President of the American Electrochemical Society, will head the convention of electrochemists to be held at the William Penn Hotel in Pittsburgh September 19th, 20th and 21st.

Dr. Frary was born July 9, 1884, at Minneapolis, Minn., son of Francis Lee Frary and Jeanette (Cowles) Frary. He graduated in 1905 from the School of Chemistry, University of Minnesota, with the degree of analytical chemist and received the M.A. degree in 1906. In 1906–07 he was at the University of Berlin and in 1912 received the Ph.D. degree from the University of Minnesota.

Dr. F. C. Frary

He was instructor, 1905–11, and assistant professor of chemistry, 1911–15, at the School of Chemistry, University of Minnesota; research chemist, Oldbury Electro-Chemical Company (Niagara Falls), 1915–17. In 1918 he was commissioned Captain, Ordnance Department O. R. C., and later, Major, Chemical Warfare Service. Since 1919 he has been Director of Research, Aluminum Company of America.

Dr. Frary is joint inventor, with Dr. S. Temple, of "Frary Metal," a popular bearing metal, manufactured by the United Lead Company. He perfected the process of manufacturing phosgene on a large scale, later used at Edgewood Arsenal, where he was jointly responsible with Major D. J. Demorest for the design and construction of the largest phosgene manufacturing plant in the world.

He is a member of: American Chemical Society (Counselor, 1917); American Electrochemical Society (Vice-President 1918–20); American Institute of Mining and Metallurgical Engineers; Institute of Metals: and of Alpha Chi Sigma and Sigma Xi fraternities.

X-Ray Metallography in 1929*

By George L. Clark†

5. Results of Analysis of Ultimate Crystalline Constitutions of Metals

1. The Chemical Elements. By the methods of X-ray analysis outlined in preceding sections of this paper more than half of the ninety known chemical elements have been assigned definite lattice structures in the solid state. Pure metals are of course chemical elements; every metal except some of the rare-earth metals and a few others of very rare occurrence in nature may be classified now according to the pattern by which its atoms form crystals, and according to the numerical values which define the unit crystal cell. Fortunately most of the metals are grouped in a very few crystal systems, the majority being face-centered and body-centered cubic and hexagonal close-packed. In addition some of the metallic elements crystallize in more than one modification, iron being an outstanding example. In the following tabulation the metals are divided into crystallographic classes; under each class are listed atomic number z, the lattice constant a (edge length of the unit cube, for example), and the radius r of the metallic atom as evaluated by Goldschmidt.[1] A few non-metallic elements which are of metallurgical importance (silicon, carbon, phosphorus) are included.

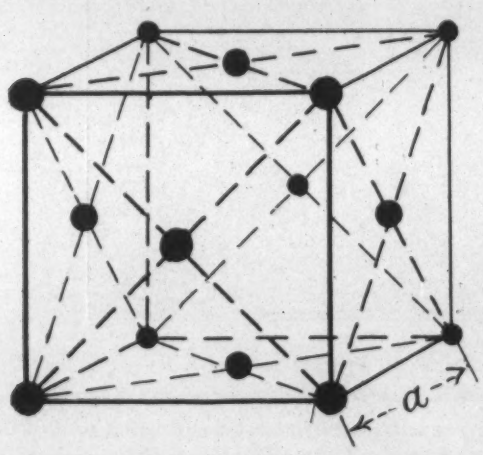


Figure 35—Face-Centered Cubic Crystal Structure

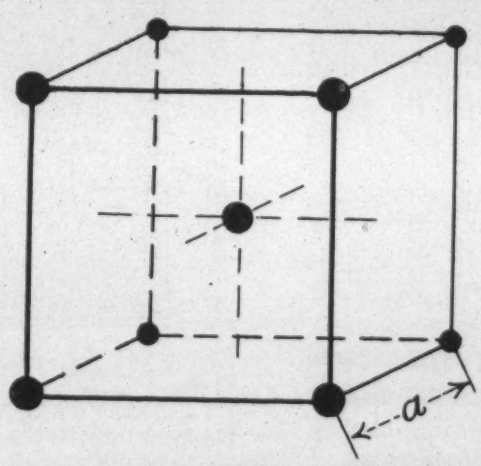


Figure 36—Body-Centered Cubic Crystal Structure

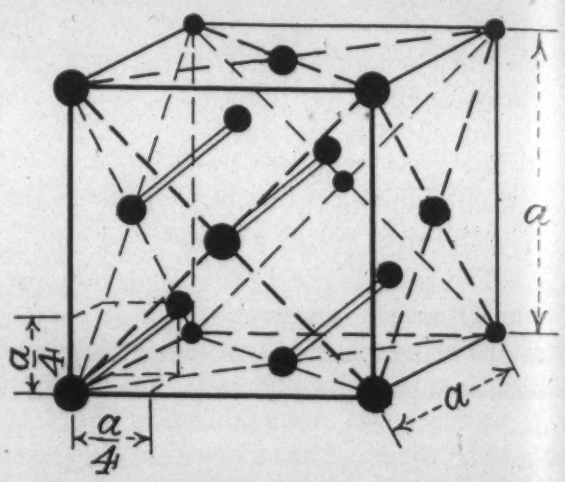


Figure 37—Diamond Cubic Crystal Structure

I. Cubic Lattice; $\sin^2\Theta = \frac{\lambda^2}{4a^2}(h^2 + k^2 + l^2)$

1. Copper type, face-centered cubic lattice (Figure 35); atom coordinates (0, 0, 0), ($^1/_2$, $^1/_2$, 0), ($^1/_2$, 0, $^1/_2$), (0, $^1/_2$, $^1/_2$); space groups O_h^4, O_h^5; 4 atoms per unit cell; coordination number (number of neighbors around each atom) 12; closest packing of spheres; characteristic diffraction lines (111), (002), (022); ordinarily associated with good ductility and malleability.

Z	Element	a	r
13	Aluminum	4.043	1.43
20	Calcium	5.56	1.97
26	γ-Iron	3.63	1.27
27	β-Cobalt	3.554	1.26
28	Nickel	3.499	1.24
29	Copper	3.603	1.28
38	Strontium	6.075	2.16
45	Rhodium	3.820	1.34
46	Palladium	3.859	1.37
47	Silver	4.079	1.44
58	β-Cerium	5.12	1.81
77	Iridium	3.823	1.35
78	Platinum	3.913	1.38
79	Gold	4.064	1.44
82	Lead	4.920	1.74
90	Thorium	5.04	1.80

2. Tungsten type, body-centered cubic lattice (Figure 36); atom coordinates (0, 0, 0), ($^1/_2$, $^1/_2$, $^1/_2$); space groups O_h^2, O_h^3, O_h^4, O_h^9; 2 atoms per unit cell; coordination number 8; characteristic diffraction lines (011), (022), (112); metals ordinarily hard and brittle.

Z	Element	a	r
3	Lithium	3.50	1.52
11	Sodium	4.30	1.86
19	Potassium	5.20 (−150° C.)	2.29
23	Vanadium	3.04	1.32
24	Chromium	2.875	1.24
26	α-Iron	2.855	1.24
	δ-Iron	2.93 (1425° C.)	
42	Molybdenum	3.143	1.36
56	Barium	5.015	2.18
73	Tantalum	3.272	1.42
74	Tungsten	3.155	1.37

3. Diamond type, two face-centered cubic lattices interpenetrating so that the corner of one unit cube is placed one-fourth of the distance along the cube diagonal of the other (Figure 37); atom coordinates as in face-centered cubic lattice with (0, 0, 0) and ($^1/_4$, $^1/_4$, $^1/_4$) considered as origins in turn; space groups O_h^7, T_d^2; 8 atoms per unit cell; coordination number 4; characteristic diffraction lines (111), (022), (311).

Z	Element	a	r
6	Diamond carbon	3.56	0.77
14	Silicon	5.43	1.17
32	Germanium	5.63	1.22
50	Tin (gray)	6.46	1.40

4. Manganese, α, β ($Z = 25$); cubic of low symmetry; 56 and 20 atoms per unit cell, respectively, and $a = 8.89$ and 6.289; characteristic diffraction lines, respectively (330), (332), (510), and (221), (310), (311).

II. Hexagonal Lattice;—$\sin^2\Theta \frac{\lambda^2}{4a^2}\left[4/3\,(h^2 + k^2 + hk) + \frac{a^2}{c^2}\,l^2\right]$

5 Magnesium-zinc type, hexagonal close-packed (Figure 38); atom coordinates (0, 0, 0), ($^2/_3$, $^1/_3$, $^1/_2$); space group D_{6h}^4; 2 atoms per unit cell; coordination number 12; in elements with an axial ratio $c/a = 2\sqrt{^2/_3} = 1.633$, close packing of spheres is indicated while for other values the atomic shape is spheroidal; characteristic diffraction lines (002), (101), (110).

Z	Element	a	c/a	r
4	Beryllium	2.283	1.58	1.13
12	Magnesium	3.203	1.622	1.60
22	Titanium	2.97	1.59	1.45
24	Chromium (1 modification) ?	2.714	1.625	1.28
27	α-Cobalt	2.514	1.633	1.26
30	Zinc	2.657	1.86	1.37
40	Zirconium	3.23	1.59	1.60

* Part 3 of an article to be published in five parts; for Part 1 see pages 14–17 of this publication, July; for Part 2 see pages 57–68 of this publication, August.

† Professor of Chemistry, University of Illinois.

[1] *Trans. Faraday Soc.*, **25**, 283 (1929).

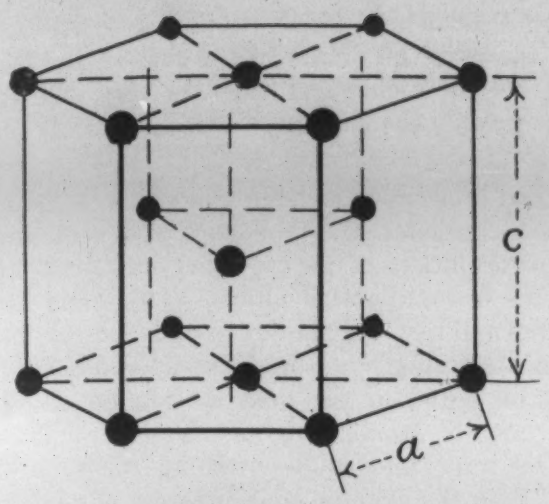


Figure 38—Hexagonal Close-Packed Crystal Structure

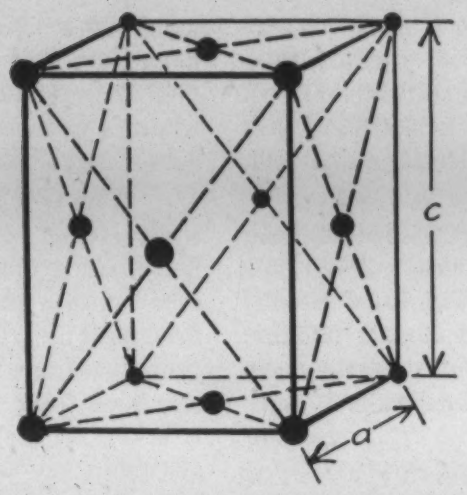


Figure 39—Face-Centered Tetragonal Crystal Structure

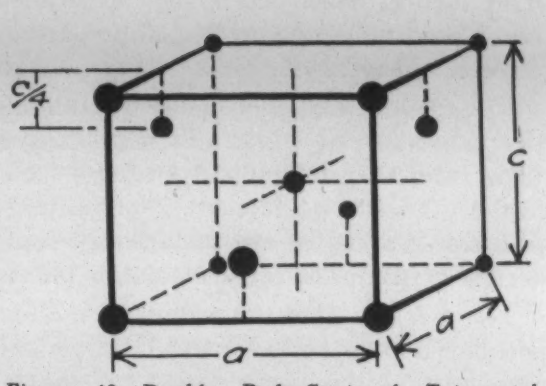


Figure 40—Double Body-Centered Tetragonal Crystal Structure

Z	Element	a	c/a	r
44	Ruthenium	2.686	1.59	1.32
48	Cadmium	2.973	1.89	1.52
58	α-Cerium	3.65	1.63	1.81
72	Hafnium	3.32	1.64	1.59
75	Rhenium[2]	2.752	1.62	1.37
76	Osmium	2.714	1.59	1.34
81	Thallium	3.449	1.599	1.71

6. Graphite (carbon, $Z = 6$); hexagonal with flat hexagons in layers; atom coordinates (0, 0, 0), (0, 0, $^1/_2$), ($^1/_3$, $^2/_3$, p), ($^2/_3$, $^1/_3$, $p + ^1/_2$), $p < 0.02$; space group C_{6v}^4; $a = 2.46$; $c/a = 2.76$; 4 atoms per unit cell; characteristic diffraction lines (001), (011), ($2\bar{1}0$). Compounds of the type CoS, FeS, FeSe, NiAs, NiS, NiSb, NiSe are similar.

III. Rhombohedral Lattice;—$\sin^2\theta = \dfrac{\lambda^2}{4a^2}$

$$\frac{(h^2 + k^2 + l^2)\sin^2\alpha + 2(hk + hl + kl)(\cos^2\alpha - \cos\alpha)}{1 - 3\cos^2\alpha + 2\cos^3\alpha}$$

7. Antimony type, rhombohedral face-centered or deformed simple cubic lattice; atom coordinates (0, 0, 0), ($^1/_2 + \Delta$, $^1/_2 + \Delta$, $^1/_2 + \Delta$); space group D_{3d}^5; 2 atoms per unit cell; characteristic diffraction lines (200), (220), ($2\bar{2}0$).

Z	Element	a	Angle	r
15	Phosphorus (black)	5.96	60° 16′	..
33	Arsenic	4.142	54° 7′	1.35
51	Antimony[3]	4.500	56° 37′	1.56
80	Mercury (−80° C.)	4.598	98° 14′	1.50
83	Bismuth	4.726	57° 16′	1.77

IV. Tetragonal Lattice; $\sin^2\theta = \dfrac{\lambda^2}{4a^2}\left(h^2 + k^2 + \dfrac{a^2}{c^2}l^2\right)$

8. Indium type, face-centered tetragonal; atom coordinates as in Type 1; 4 atoms per unit cell; space groups D_{4h}^4, D_{4h}^6, D_{4h}^9, D_{4h}^{12}, D_{4h}^{14}, D_{4h}^{15}, D_{4h}^{17} (Figure 39).

Z	Element	a	c/a	r
25	γ-Manganese	3.774	0.937	1.38
49	Indium	4.58	1.06	1.57

9. White tin ($Z = 50$) stable above 18° C.; double body-centered tetragonal; atom coordinates (0, 0, 0), (0, $^1/_2$, $^1/_4$), ($^1/_2$, 0, $^3/_4$), ($^1/_2$, $^1/_2$, $^1/_2$); space group D_{4h}^{19}; 4 atoms per unit cell; $a = 5.818$; $c/a = 0.545$; $r = 1.53$ (Figure 40).

10. Gallium ($Z = 31$); simple tetragonal; atom coordinates (0, 0, 0), (0, $^1/_2$, 0), (0, 0, $^1/_2$), ($^1/_2$, 0, 0), ($^1/_2$, $^1/_2$, 0), ($^1/_2$, 0, $^1/_2$), (0, $^1/_2$, $^1/_2$), ($^1/_2$, $^1/_2$, $^1/_2$); 8 atoms per unit cell; coordination number 6; $a = 4.51$; $c/a = 1.665$.

2. Allotropic Modifications. As is apparent from the foregoing tables a few of the metallic elements crystallize in more than one crystallographic system, each representing a stable arrangement of the atoms in the crystal unit over a definite temperature range. Sometimes two modifications are present simultaneously. The phenomena accompanying transformation from one stable form to another, and the factors influencing retention of a form outside the limits of stability are frequently of great practical importance as they influence the properties and behavior of metals and alloys.

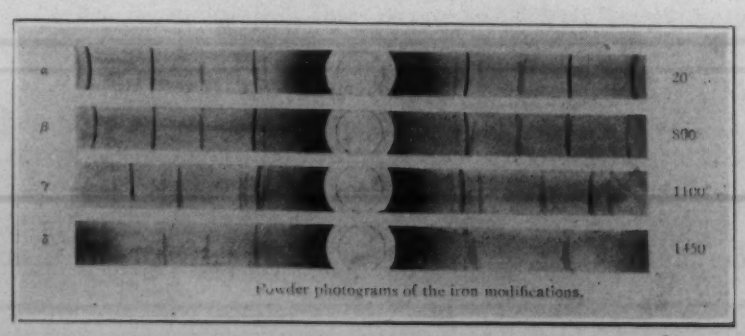
Iron.—Thermal, microscopic and magnetic researches long ago proved that there are four allotropes of pure iron. X-ray analysis of the crystalline forms has led to the identification shown in the following table (there is no X-ray evidence of β-iron).

Modification	Magnetic properties	Temperature Range, Degrees	Lattice Type	Unit Cell a	No. of Mols.	Calculated Density
α	+	Below 800	Body-centered cubic	2.855	2	7.92
β	−	800–900	Body-centered cubic	2.90 (at 800°)	2	
γ	−	900–1400	Face-centered cubic	3.63 (1100°)		7.70 (1100°)
				3.68 (1425°)	4	7.40 (1450°)
δ	+	Above 1400	Body-centered cubic	2.93 (1425°)	2	7.33 (1425°)

Westgren and Phragmen's spectra of the allotropes of iron obtained with a Debye-Scherrer type camera are reproduced in Figure 41. The transition from α to γ is intimately concerned in the preparation of iron alloys, for the addition of some elements raises the transformation point and the addition of others lowers it. Under some conditions γ-iron may exist at room temperatures. The iron-carbon alloys are considered in the next section.

Great interest has been aroused recently in the allotropic modifications of iron on account of the theory of T. D. Yensen[4] that genuinely pure iron should have no allotropic transformations. Iron containing 0.008% carbon has been regarded commonly as pure iron. In amounts less than this the carbon as well as small amounts of oxygen or nitrogen are in solid solution in the iron and apparently have a profound influence

[4] Am. Inst. Mining Met. Eng., *Tech. Publication* **185** (Feb., 1929).



Powder photograms of the iron modifications.

Figure 41—Patterns for the Allotropic Modifications of Iron (Westgren and Phragmen)

[2] Goldschmidt, *Naturwissenschaften*, **17**, 134 (1929).

[3] The values given by Persson and Westgren, *Z. physik. Chem.*, **136**, 208 (1928), are 6.226 and 87° 24′ for the cell measured in a different direction.

on physical properties and possibly in causing a lattice change from body-centered to face-centered cubic (α,β–γ transformation), and vice versa above 1400° C. (γ–δ transformation). This theory, which has a good experimental background, has stimulated numerous efforts to prepare iron free from carbon, oxygen and nitrogen.

Cerium and Cobalt.—These two metals crystallize in both the face-centered cubic and the hexagonal close-packed lattices; and at ordinary temperatures each is a mixture of both forms. These two lattices, representing the closest possible packing of spheres, are remarkably similar in that they are derivable from each other by simple planar translations.

Tin.—White tin, the ordinary modification, has its own peculiar double body-centered tetragonal structure. At low temperatures this variety may suffer "tin pest," which is the gray, diamond-cubic, brittle modification.

Manganese.—The excellent researches of Westgren and Phragmen[5] have proved the existence of three modifications of manganese as follows:

Type	Preparation and Stability	Lattice Type	Dimensions	No. of Atoms per Unit Cell	Calculated density
α	Ordinary	Cubic	8.894	56	7.21
β	Higher temperatures	Cubic	6.289	20	7.29
γ	Electrolytic	Face-centered tetragonal	a 3.774 c 3.533 c/a 0.937	4	7.21

Other Metals.—There is some evidence of allotropes of thallium (hexagonal close-packed and tetragonal), and of chromium (body-centered cubic and hexagonal close-packed). Several unsuccessful efforts have been made to find new modifications of nickel and zinc particularly; the first, because of the change in its magnetic properties, and the second, because of its occasional behavior as a cubic metal in alloys. Aluminum also has given some evidence of another form at high temperatures which might explain the changes in duralumin. Alichanow[6] has demonstrated by X-ray analysis that up to 593° C. no transformation occurs. It must be emphasized, however, that the X-ray examination of allotropic transformations under high temperatures, high pressures or both, is an unexplored field of investigation. As experimental technique is improved, many unsuspected instances of allotropy will undoubtedly come to light.

3. General Relationships of Structure and Properties of Crystalline Metals. The following conclusions may be drawn from a consideration of the data obtained by X-ray analysis of crystalline structure of metals:

a. The periodic arrangement of elements is, in general, carried over into the types of crystalline structures; there is an easily observed tendency for elements in the same periodic column or family to crystallize in the same way. There are notable exceptions, as, for example, the discovery in the writer's laboratory that calcium and strontium are face-centered cubic and barium is body-centered cubic.[7] Other complexities are the unusual structures of α- and β-manganese which have remarkable analogues among the alloys and the cases noted above of entirely distinctive structures for white tin, etc.

b. As noted in a preceding section all evidence, including the interpretation of the new quantum mechanics, points to the fact that true crystalline metals are built up from positive ions in an electron gas. This electron gas, so-called, is a primary determining factor. In ordinary ionic lattices for chemical compounds in which electrostatic forces between positive and negative ions hold these at the points of the lattice, the elements, magnesium, cobalt, nickel and zinc are very similar, whereas in metallic crystals the similarity is retained only for cobalt and nickel.

c. The best method of arriving at definite conclusions as to the relation between characteristic properties and structure is to observe the transformations of one type of crystal structure into another in series of comparable alloys. This logic has been used by Westgren and by Goldschmidt to derive important generalizations from a seemingly hopelessly complicated field. Some of these will be noted in the next section on alloys. It is certain that for metals, atomic weights or atomic numbers are relatively far less important in determining the type of crystalline structure than the average concentration of valence electrons. In other words, the most important factors are the polarization properties of the atoms. Goldschmidt[8] draws an analogy between a radical such as ammonium (NH_4) which acts as a *polynuclear pseudo atom*, and a single metal crystal, no matter how large, which is also a *polynuclear pseudo atom* on account of the common electron shell (gas) around the positive kernels. In terms of modern theories of the structure of matter this accounts for all those properties characteristically associated with the metallic state-allotropy, transformations, common behavior in polyphase systems, the solubility of hydrogen in solid metal crystals[9] (in the form of hydrogen kernels), the electron emission from heated metals as an ionization leaving the whole metal crystal as a *macroscopic cation*, electron isomerism and passivity. Even molten metals are polynuclear pseudo atoms, and only in vaporization do the single atoms regain their individuality.

In a masterly paper just published on the problem of the metallic state, J. D. Bernal[10] summarizes the evidence concerning the metallic bond as follows:

1. It must be capable of acting between identical atoms and at the same time between atoms of very different constitution (as in intermetallic compounds), the only limit being that the majority of atoms concerned should be metallic.

2. It should be undirected, as is shown by its identity and almost equal efficacy in the liquid state, and unsaturated, that is, it should permit always of the highest coordination number sterically possible. This number in some alloys rises as high as 16.

3. Its force must vary inversely as some high power of inter-nuclear distance as shown by its extreme weakness in the alkaline metals, with low melting points and very large atomic volumes, by the high value of the thermal energy of titanium and by the low atomic volume of the platinum group. There must be some difference between the forces concerned with thermal and mechanical effects.

4. In equilibrium with this force of attraction there must be a force of repulsion which is an atomic property as shown by the *constancy of atomic volume* in alloy formation. (This is the most difficult fact to explain on the theory that conductivity electrons belong to the lattice, as a whole, and not to single atoms.)

5. The bond must allow a transfer of electrons from one atom to another to account for the electrical properties.

6. The Analysis of Alloy Systems

1. Types of Alloys. The phenomena which occur when two metals are melted together and allowed to cool have long been known. Microscopic thermal, dilatometric and electrical

[5] *Z. Physik*, **33**, 777 (1925).
[6] METALS & ALLOYS, **1**, 30 (1929).
[7] Clark, King and Hyde, *Proc. Nat. Acad. Sci.*, **14**, 617 (1928); **15**, 337 (1929); *J. Am. Chem. Soc.*, **51**, 1709 (1929). Also Ebert and Hartmann, *Z. anorg. allgem. Chem.*, **179**, 418 (1929).
[8] *Ber.*, **60**, 1263 (1927); *Trans. Faraday Soc.*, **25**, 253 (1929).
[9] Also helium in platinum, with X-ray evidence of compound formation; cf. Damianovitch and Trillat, *Compt. rend.*, **188**, 991 (1929).
[10] *Trans. Faraday Soc.*, **25**, 367 (1929).

methods have demonstrated the formation of "mixed crystals" or solid solutions of eutectic mixtures and of chemical compounds. In binary alloys all of these conditions are found in various combinations.

a. Alloys Formed by a Continuous Series of Solid Solution

Microscopic evidence: only one kind of crystals appear in any specimen ranging from one pure component to the other.

Thermal evidence: smooth continuous curve in phase diagram between pure components. Very slow cooling or careful annealing to permit diffusion is necessary to assure that all the crystals separating from the liquid phase are uniform in composition since 2 "nicks" appear in cooling curves.

X-ray evidence: only one type of diffraction pattern throughout, the only variation being a change in the lattice parameter. Figure 42 shows how the diffraction lines for a pure metal are shifted in a solid solution.

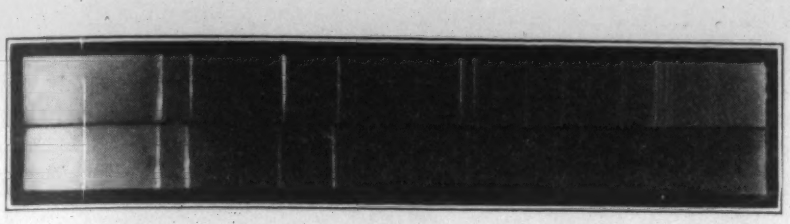


Figure 42—Crystal Spectra for Pure Copper (above) and 80–20 Brass (below) Illustrating Solid Solution and the Expansion of the Copper Lattice by Substitution of Zinc Atoms (the Lines Being Shifted to Smaller Angles Corresponding to Larger Interplanar Spacings)

Requirements: only two metals which have the same lattice structure (that is, both face-centered cubic, for example) can form a continuous series of solid solutions. All pairs of metals with common lattice structure do not form continuous series (e. g., aluminum-gold).

Additivity relations: Vegard's law of additivity states that in a binary system forming a continuous series of solid solutions the lattice parameters are linearly related to atomic percentage of one of the components. In other words, upon a straight line joining the numerical values of the edge lengths of the unit, crystal cells of the two pure metals, lie all the lattice values for all possible solid solutions of the two metals.

Examples investigated by X-rays: Gold-copper, gold-silver, gold-palladium, nickel-copper, tungsten-molybdenum, cobalt-nickel, nickel-palladium, iron-vanadium, platinum-palladium, potassium-rubidium, strontium-calcium (unpublished), etc.

b. Systems with a Eutectic

Microscopic evidence: mechanical mixture of two kinds of crystals usually identified as the pure components.

Thermal evidence: liquidus curve sharply discontinuous with separation of crystals at lower temperature than that for the pure metals or intermediate mixtures.

X-ray evidence: diffraction patterns for both metals superposed.

Example: lead-silver alloys. In an alloy with 1% silver, pure lead crystals will first separate until a composition of 2.5% silver is reached, whereupon at 304° C. both lead and silver crystals separate together in constant ratio.

c. Systems with Compound Formation

Microscopic evidence: doubtful, 2 kinds of crystals, unless the specimen has the exact constitution corresponding to a definite chemical compound.

Thermal evidence: maximum in the melting point curve.

X-ray evidence: limited solid solutions of A in B and B in A, or lattices of both A and B, compound A_xB_y with different characteristic lattice, and solid solutions or mechanical mixtures of A and A_xB_y and of B and A_xB_y.

Example: In the system lead–magnesium (Sacklowski), X-ray data show a series of mixtures, from 0–81% lead, of magnesium and the compound $PbMg_2$; at 81% lead a face-centered cubic lattice for $PbMg_2$ with an edge length of 6.76 A. U.; and at higher lead contents, mixtures of lead and $PbMg_2$ lattices.

2. The Mechanism of Solid Solution. By means of X-ray, thermal and density measurements, two kinds of solid solutions are recognized: (1) substitutional, in which atoms of one kind of metal which is being alloyed with another, replace the atoms of the latter at the lattice points. In most cases this is a simple process but in other cases as in copper-aluminum alloys complex substitution may involve replacing 3 by 2 atoms, etc.; (2) interstitial, in which alloying atoms do not substitute for atoms of the original metal but enter the empty spaces between the atoms. The best example of the latter is carbon in iron. The two types of solid solution may be distinguished by density measurements. Glocker[11] gives the following example from the work of Westgren and Phragmen:

Austenitic steel with 12.1% manganese and 1.34% carbon has a face-centered cubic lattice with $a = 3.624$ A. U. The two possibilities are that these alloying elements are substitutes for iron atoms, or that the manganese atoms are substitutional and the carbon interstitial. The average atomic weight, calculated from the atomic weights of three elements, iron, manganese and carbon in given percentages is given by

$$A = \frac{100}{\frac{86.56\ (\%)}{55.85\ (\text{at. wt. Fe})} + \frac{12.1\ (\%)}{54.93\ (\text{at. wt. Mn})} + \frac{1.34}{12\ (\text{at. wt. C})}} = 53.13$$

Substituting this in the density formula presented earlier in this paper

$$\rho = \frac{n\text{Mn}}{\text{vol. unit cell}} = \frac{4 \times 53.13 \times 1.65 \times 10^{-24}}{(3.624 \times 10^{-8})^3} = 7.36$$

This is the density, therefore, on the substitutional basis.

For the other case the average atomic weight for iron and manganese is 55.74. To each 55.74 grams (iron + manganese) are added interstitially $\frac{1.34}{98.66} \times 55.74 = 0.757$ gram of carbon. The average atomic weight is therefore $55.74 + 0.757 = 56.497$ and

$$\rho = \frac{4 \times 56.497 \times 1.65 \times 10^{-24}}{(3.624 \times 10^{-8})^3} = 7.83$$

The actual experimental density is 7.83 proving that the second alternative of interstitial carbon is correct.

The interstitial type of solid solution is usually unstable and limited to only a few percent of one component (the solubility of carbon in iron is about 0.1% in body-centered and 1.7% in face-centered cubic). Heat treatment may destroy this condition. There has been much conjecture as to whether the interstitial carbon atoms in iron alloys are fixed in position or are free to move. In a paper on the absence of allotropy in pure iron, Yensen[4] shows how the thermal agitation of atoms is large at high temperatures and how the small carbon atoms may travel from one cube to another. If the concentration is low enough no distortion may result, but with increasing concentrations the lattice may change over because of distortions to face-centered cubic, in which the solubility is greater. At still higher concentrations (6.67%) exceeding the powers of the γ-iron, the compound cementite Fe_3C is formed. Similarly nitrogen which has a maximum solubility of 0.5% in α-iron may cause the lattice transformation and then the formation of Fe_4N. Oxygen with a maximum solubility of 0.2% may behave similarly.

3. The Distinction between "Chemical Compound" and "Solid Solution." From the X-ray point of view the most interesting phases of alloy research are the intermetallic compounds and the solid solutions. The question which is still frequently agitated is just what is the boundary line between

[11] "Materialprüfung mit Röntgenstrahlen," Berlin, **1927**, page 281.

the two. Westgren and Phragmen, outstanding masters in the X-ray science of alloys, some years ago made the following differentiation: "In an ideal solid chemical compound, structurally equivalent atoms are chemically identical. In an ideal solid solution, all atoms are structurally equivalent."

In the case of iron-nickel alloys, for example, the forces of combination of a definite number of nickel atoms with iron are not sufficiently strong to overcome the forces of diffusion. There is a geometric chance, however, for the compounds Fe_3Ni (20% nickel, face-centered cubic), FeNi (51%) and $FeNi_3$ (76%). Efforts have been made to identify these among the series of alloys, based upon Tammann's theory, but without avail, hence they may be regarded as very weak compounds or merely as stages in the continuous solid solutions. In one sense an intermetallic compound may be regarded as a solid solution in which the forces of combination are stronger than those of diffusion. $CuAl_2$, FeSi and $FeSi_2$ have been clearly considered as chemical compounds, on the basis that structurally equivalent atoms are chemically identical. The explanation of the fact that the composition of such phases as these corresponds to simple stoichiometric proportions is sought therefore in the crystal structures. However, more recently some cases have been found where the composition corresponds with constant and simple stoichiometric proportions without reference to regularity in the crystal structure. Westgren and Phragmen[12] point out the case of Ag_3Al which has a crystal structure apparently isomorphous with β-manganese, even to the relative intensities of X-ray interferences. (See the pattern for the β phase, Figure 43.) Preston[13] has shown that the 20 atoms of manganese in the unit cell are divided into two groups, one containing 12 and the other 8 equivalent atoms. Now in Ag_3Al the fifteen silver atoms cannot all be unequivalent to aluminum atoms, and any possible division of the two kinds of atoms into unequivalent groups will yield entirely different intensity relationships than in β-manganese. The inevitable conclusion, therefore, is that the silver and aluminum atoms are distributed *at random* and approximately uniformly over the two groups of structurally equivalent atomic positions. From the standpoint of constant and simple stoichiometric proportions Ag_3Al is a chemical compound; from the standpoint of crystal geometry and the earlier definition of Westgren and Phragmen it is not. The explanation of proportions must, therefore, be sought elsewhere than in structural equivalence, and probably in the ratio of valency electrons to atoms as explained later.

[12] *Trans. Faraday Soc.*, **25**, 379 (1929).
[13] *Phil. Mag.* (VII), **5**, 1198 (1928).

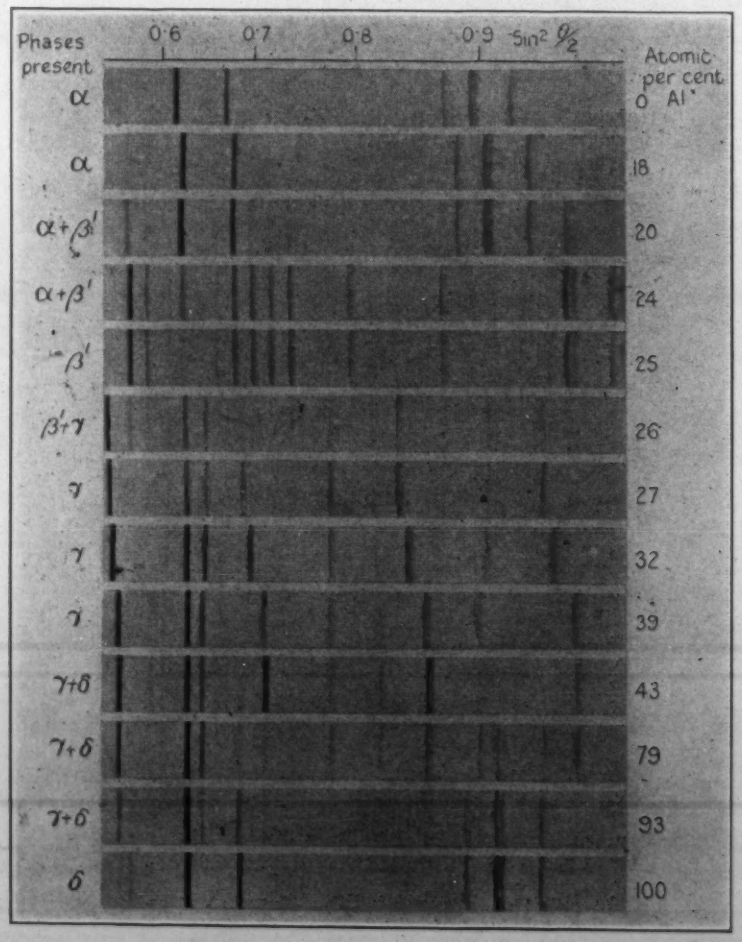


Figure 43—Powder Photograms of Silver-Aluminium Alloys. Fe-K Radiation. (Westgren and Bradley)

4. X-ray Results on Alloy Systems. The following tabulation represents as nearly all the X-ray data on alloy systems as have been possible to assemble.[14] While it is evident that a great many papers have been published particularly in the past two years and that most of the present information on the metallic state, valence, atomic structure and general analogies have been obtained from a knowledge of how metals combine, still the great part of the field is unexplored. First in the field of alloy structure and constitution stands Professor A. F. Westgren of Stockholm, who, with Dr. G. Phragmen and other co-workers, has carried out a series of experimental researches with X-ray methods which finds no superior in science. In the Stockholm laboratory have been perfected all the standard methods of analysis and interpretation. In the face of widespread doubt and criticism there were reported the large unit cells of γ-brass (52 atoms), δ-bronze (416 atoms), α- and β-manganese, etc., only to demonstrate that these results were correct. It is one of the privileges of X-ray workers to pay tribute to the untiring skill and invaluable contributions of Professor Westgren whose photograph is herewith reproduced (Figure 44). Diffraction patterns made in the Westgren researches, on the systems silver-aluminum, copper-magnesium, and iron-tungsten and iron-molybdenum are reproduced in Figures 43, 45 and 46, respectively. The camera used was of the focussing type with slit, specimen and film on the same circumference, similar to the Seemann-Bohlin instrument shown in Figure 47. Single crystal patterns for $CuMg_2$ were shown in Figures 19 and 20 (METALS & ALLOYS, **1**, 57 (1929)).

Photo by Kaudern, Stockholm

Figure 44—Professor Arne F. Westgren, Director of the Metallographic Institute of the University, Stockholm, Sweden; Pioneer and Leading Authority in the X-ray Study of Alloys

5. Analogies and Generalizations from the Study of Alloys. It is always the method of science to try to find a thread of generalization or correlation running through a mass of experimental facts. Alloy formation seems at first sight to be hopelessly complex, but X-ray investigations primarily in the laboratory of Westgren have disclosed orderly processes and relationships where other methods have fallen short. Some of these analogies have been summarized recently in a paper by Westgren and Phragmen,[15] and because of the fact that the presentation cannot be improved, it is given here in part.

"Three years ago W. Hume-Rothery[16] suggested that the

[14] I am deeply indebted to Dr. W. H. Jennings, Jr., Chemistry Department, Iowa State College, for his assistance in a thorough search of the literature and the compilation of data.
[15] *Trans. Faraday Soc.*, **25**, 379 (1929).
[16] W. Hume-Rothery, *F. Inst. Metals*, **35**, 295 (1926).

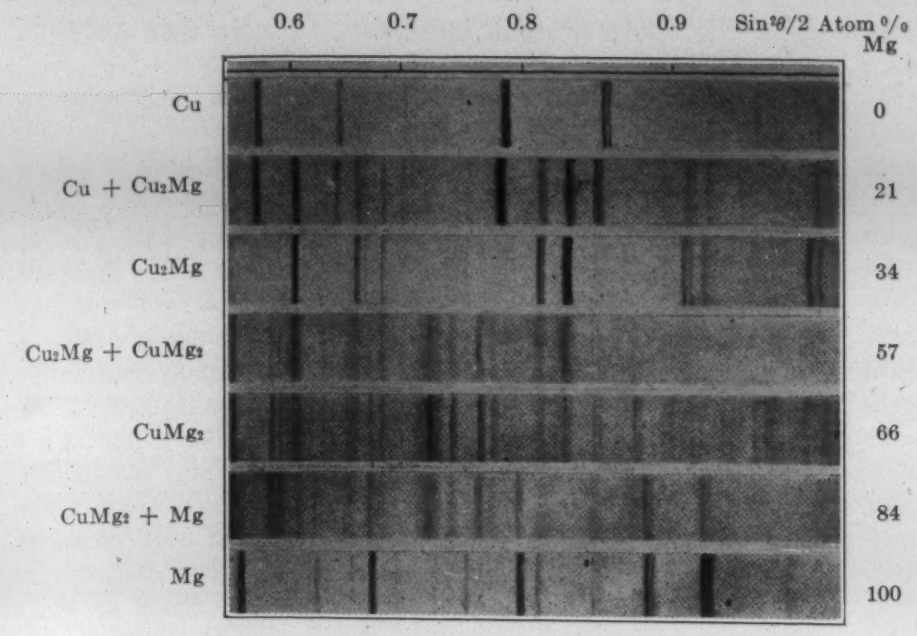


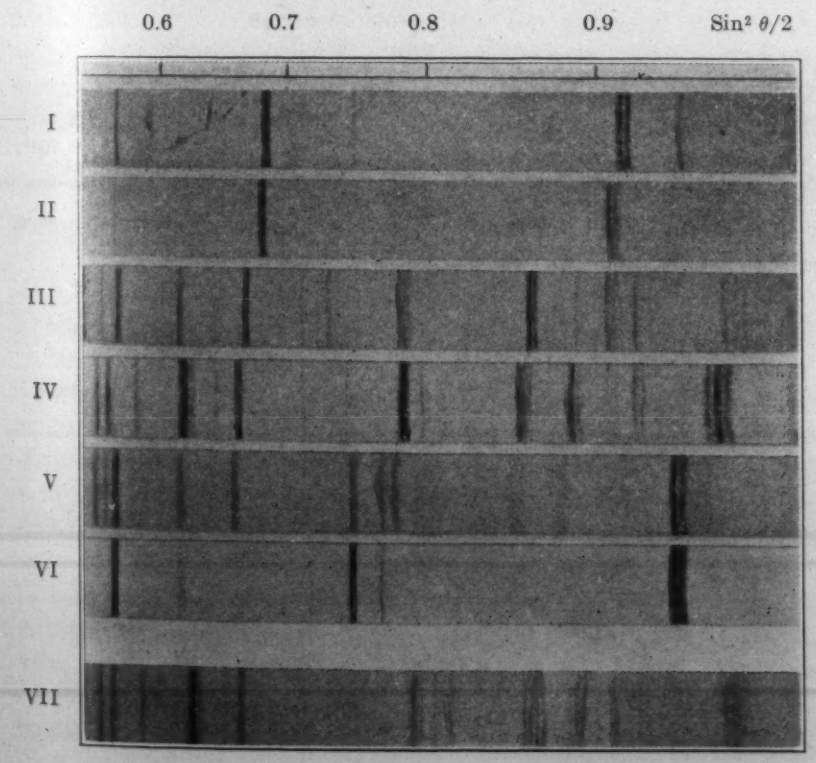
Figure 45—Powder Spectrograms of Copper-Magnesium Alloys. (Runqvist, Arnfelt and Westgren)

β-phases of the system Cu–Zn, Cu–Al and Cu–Sn are analogous in structure. As their compositions correspond approximately with the formulae CuZn, Cu_2Al and Cu_5Sn, he also put forward the hypothesis that their structural similarity might be due to the fact that in each case the ratio of valency electrons to atoms is 3 : 2.

"X-ray investigations have confirmed the assumption that the said phases have the same type of structure.[17,18,19] In each case the atoms occupy the points of a body-centered cubic lattice. In the β-Cu-Sn-phase the Cu and Sn atoms seem to be distributed at random over the lattice points, but in β-Cu-Zn and β-Cu-Al the different kinds of atoms are mainly oriented in networks of their own, forming what may be denominated 'super-lattices.'

"Phases of this structure have been found in several binary alloys of Cu, Ag and Au with other metals and, in fact, they all occur at concentrations making the ratio of valency electrons to atoms about 3 : 2.

[17] A. Westgren and G. Phragmen, *Phil. Mag.* (VI), **50**, 331 (1925).
[18] E. Persson, *Naturwiss.*, **16**, 613 (1928).
[19] A. Westgren and G. Phragmen, *Z. anorg. Chem.*, **175**, 80 (1928).



I = Fe.
II = Fe, saturated with W.
III = Fe_2W.
IV = Fe_3W_2.
V = Fe_3W_2 + W.
VI = W.
VII = Fe_3Mo_2.

Figure 46—Powder Photograms of Metals and Alloys of the Iron–Tungsten and Iron–Molybdenum Systems. Fe-K Radiation. (Arnfelt)

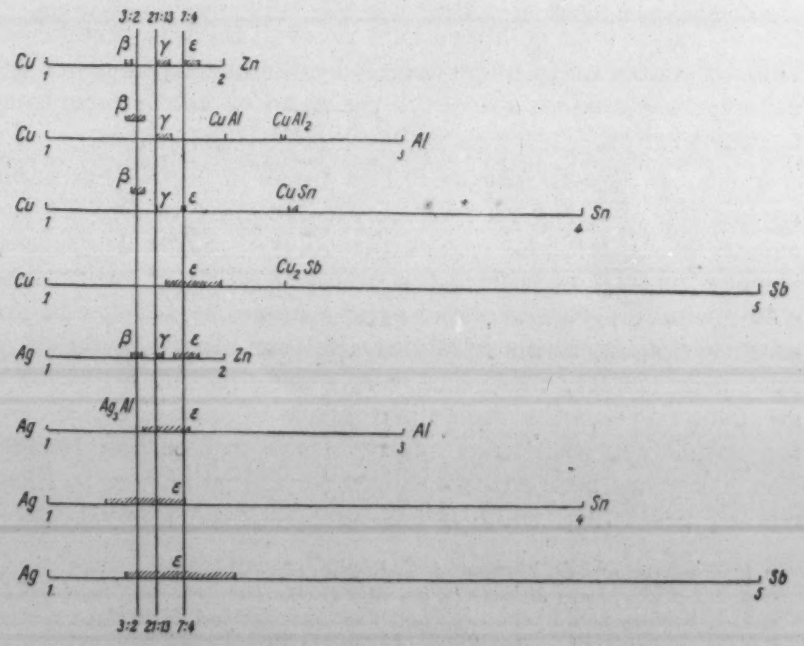
Figure 47—Seemann-Bohlinn Powder Diffraction Camera, with Slit, Specimen and Film on Same Circumference, Similar to Type Used in Studies of Alloys by Westgren and Coworkers

"This simple type of structure is not, however, the only one common to the alloys. In many cases a phase (γ) of a complicated cubic structure has been found, having usually 52, but in some cases 8 × 52, i. e., 416 atoms in its elementary cube. When Cu, Ag or Au are combined with a bivalent metal (Zn, Cd . . .) the homogeneity range of this phase corresponds to formulae of the type Cu_5Zn_8, Ag_5Cd_8 . . . and if they are alloyed with a trivalent metal (Al . . .), the concentration interval of the phase includes values corresponding to formulae of the type Cu_9Al_4. In these phases there are 21 valency electrons to 13 atoms. The type of phase present in the Cu–Sn system has an extremely narrow range of homogeneity. It is homogeneous at 32.6 percent Sn,[18] as shown by Heycock and Neville,[20,21] corresponding to $Cu_{31}Sn_8$, which gives again 21 valency electrons to 13 atoms.

"The close-packed hexagonal structure (ε), an atomic grouping which seems, moreover, to be connected with a certain concentration of valency electrons, is also commonly present in these systems.

"This connection between atomic grouping and concentration of valency electrons has been treated more in detail in previous papers,[22,23,24] to which reference may be made. It may suffice to reproduce here a graphical presentation of the regularities found. Figure 48 gives a survey of the occurrences of analogous phases in some binary Cu and Ag alloys. The

[20] C. T. Heycock and F. H. Neville, *Phil. Trans.*, **202**, 1 (1904).
[21] J. D. Bernal, *Nature*, **122**, 54 (1928).
[22] A. Westgren and G. Phragmen, *Arkiv. for mat., astron. och fysik.* (Acad. of Sciences, Stockholm), **19B**, No. 12 (1926).
[23] A. Westgren and G. Phragmen, *Z. Metallkunde*, **18**, 279 (1926).
[24] A. Westgren and G. Phragmen, *Metallwirtschaft*, **7**, 700 (1928).



Increasing Concentration of Valence Electrons

Figure 48—Graphical Representation by Westgren and Phragmen of Structural Analogies and Common Ratios of Total Number of Valence Electrons to Total Number of Atoms, for Some Copper and Silver Alloys

homogeneity ranges of the intermetallic phases in the different systems are here indicated on one and the same scale, denoting the concentration of valency electrons. As will be seen, the homogeneity intervals of analogous phases all include, or come very close to, certain common concentration values indicated by vertical lines in the figure.

"A new feature in these regularities of structural analogies has been discovered recently. Of the four elements in the series vanadium, chromium, manganese and α-iron, all but manganese are characterized by a body-centered cubic lattice. Manganese seems to be a unique element as regards its crystal structure; it crystallizes in two different forms both of which are very complicated.[25,26] The modification which is stable at ordinary temperature, α-manganese, is cubic, having 58 atoms in its elementary cube,[27,28] and β-manganese, stable at higher temperatures, is also cubic, but its elementary cube contains only 20 atoms.[29] The latter modification is of special interest in connection with the crystal structure of certain compound metallic phases.

"In some cases when in an alloy the ratio of valency electrons to atoms is 3 : 2 and a phase having a body-centered cubic lattice might thus have been expected, the atoms have instead been found to be grouped in the same way as in β-manganese. Just as this metal differs from its neighbouring elements in respect to crystal structure, these intermetallic phases, for some reason, form exceptions from the general rule.

"A phase of this kind is found in the Ag–Al system.[30] Its range of homogeneity is so narrow that it may be denoted by a mere line in the equilibrium diagram. Its composition corresponds to Ag_3Al, from which it is evident that its ratio of valency electrons to atoms is 3 : 2. A preliminary X-ray analysis of some Au-Al-alloys has indicated that an analogous phase (Au_3Al) is present also in this system.

"Just recently at this Institute, by analyzing the Cu-Si alloys Sven Arrhenius has met with a new representative of these peculiar phases of β-manganese structure. Its interference lines have just the same position, when it is in equilibrium with one or other of its neighbouring phases, from which it may be concluded that it also has a narrow range of homogeneity. It has not yet been chemically analyzed, but from the proportions of copper and silicon weighed together before the production of the alloy, as well as from a thermal analysis recently carried out by Matuyama,[31] it is most probable that its composition corresponds to Cu_5Si. In this phase too, the ratio of valency electrons to atoms seems thus to be exactly 3:2.

"Further cases of this kind will certainly be met with in the future, and it is to be hoped that we shall then have sufficient data to enable us to understand why the one structure or the other presents itself, whenever the ratio of valency electrons to atoms is 3 : 2."

6. Steel (Fe-C Alloys). The most important possible application of X-ray analysis to the structure of alloys is, of course, to the series of iron-carbon alloys. There are several reasons for this, aside from the practical utility of steel. The equilibrium diagram is one of great complexity because of the great variety of forms involving the four allotropic forms of pure iron; hence, there has been among metallurgists for a great many years the widest divergence of opinion concerning the actual constitution of many of the iron-carbon phases. The X-ray has been eagerly sought for a final answer to these mooted problems; while it has already given many hopeful signs, the results are still insufficient to more than open the subject.

The facts established by X-ray analysis of steel may be briefly summarized as follows:

1. *Austenite*, formed by quenching Fe-C alloys from above the A_3 transformation point, has the structure of γ-iron (face-centered cubic). Carbon causes an enlargement of the lattice. Westgren and Phragmen found the dimensions of the unit cell to be 3.629 A. U. for a saturated solution (1.7 percent) quenched from 1100° C., and 3.606 A. U. for a specimen containing 0.9 percent C quenched from 750° C. A specimen containing 12.1 percent Mn and 1.34 percent C had a parameter 3.624 A. U. As already explained, the carbon atoms are placed interstitially. The carbon may be atomically and irregularly dispersed or the atoms may be more definitely arranged, in the sense that an atom of γ-iron may be replaced by a complex of an iron atom combined with one or more carbon atoms. In other words, austenite is a solid solution of carbon or Fe_3C (cementite) in γ-iron.

2. *Cementite.*—The only definite compound formed by iron and carbon, Fe_3C, crystallizes in the orthorhombic system. The unit parallelopiped has the dimensions 4.518 by 5.019 by 6.736 A. U. or the axial ratios 0.671 : 0.753 : 1. This compound is found in *pearlite* (the eutectoid mixture of α-iron and cementite formed by slow cooling of austenite from the transformation point), *troostite* (α-iron and cementite in colloidal dispersion), *sorbite*, and in the massive spheroidal condition. Meteoric cohenite has the same structure (Figure 49).

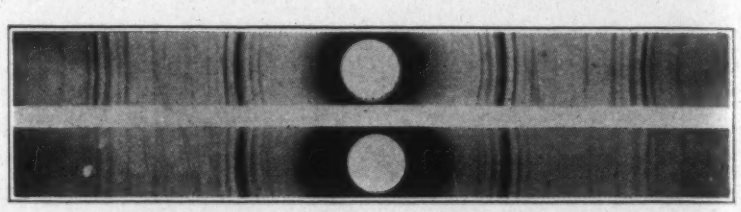


Figure 49—Powder Photograms of Cementite and Cohenite. (Westgren and Phragmen)

3. *Ferrite* has the body-centered cubic structure of pure α-iron. Carbon has a very limited solubility in it, since the diffraction lines for the numerous specimens have the same position as for pure electrolytic α-iron. A widening of the lines and the disappearance of the resolution of doublet lines may be taken as an indication of a slight increase (up to 0.3 percent) in the lattice, but non-uniformly, since pure iron dimensions are still indicated.

4. *β-Iron.*—There is no X-ray evidence of β-iron, since there is no structural discontinuity between α- and γ-iron.

5. *Martensite.*—This interesting constituent found in hardened steel has received more attention than any other phase of X-ray analysis of alloys. Martensite is formed and retained at room temperatures when the γ-α transformation is delayed by sufficiently rapid cooling until a temperature of 300° C. is reached. The cooling may be slower in the presence of retarding elements such as nickel and manganese. The simple facts were first established that martensite gives the spectrum of α-iron and that the diffraction lines are broad and diffuse.

More careful technic in the preparation of samples and in photographing diffraction spectra have served to clarify the problem. Fink and Campbell[32] found evidence in drastically quenched eutectoid and hypereutectoid steels of a body-centered tetragonal structure. This was not uniform with lower carbon contents, but with 1.5% carbon the value of a was 2.85 A. U. and of c, 3.02 A. U. (body-centered cubic α-iron, a = 2.86 A. U.). It was found to be less stable at low temperatures

[25] A. Westgren and G. Phragmen, *Z. Physik*, **33**, 777 (1925).
[26] A. J. Bradley, *Phil. Mag.* (VI), **50**, 1018 (1925).
[27] A. J. Bradley and J. Thewlis, *Proc. Roy. Soc.*, **A115**, 456 (1927).
[28] G. D. Preston, *Phil. Mag.* (VII), **5**, 1198 (1928).
[29] *Ibid.*, **5**, 1207 (1928).
[30] A. Westgren and A. J. Bradley, *Phil. Mag.* (VII), **6**, 280 (1928).
[31] Kanji Matuyama, *Science Reports Tohoku Imp. Univ.* (I), **17**, No. 3 (1 28).
[32] *Trans. Am. Soc. Steel Treating*, **9**, 717 (1926).

than the γ-iron lattice and disappeared on tempering at 100° C. Bain then showed that the face-centered cubic lattice can be considered as a body-centered tetragonal lattice with an axial ratio of $\sqrt{2}$ and $a = 2.54$ and $c = 3.60$ A. U. Of this, the body-centered cubic lattice would be a special case with axial ratio 1. Hence, the martensitic tetragonal structure might represent an arrested stage in the transformation from face-centered cubic (γ) to body-centered cubic iron (α). This discovery was confirmed by Seljakow, Kurdjumow, and Goodtzow,[33] who showed further that the axial ratio c/a increases with carbon content at constant heating and quenching conditions and with the temperature before quenching at constant carbon content. Honda and Sekito[34] found still later that the outer layer of quenched carbon steel contains a body-centered tetragonal lattice, β-martensite, and the inner portion a body-centered cubic lattice, α-martensite, with a gradual change in the axial ratio from 1.07 to 1. Upon annealing, the tetragonal structure gradually changes to cubic without passing through a stage of an intermediate axial ratio. Kurdjumow and Kaminskii,[35] however, maintain that the tetragonal structure exists on the interior of quenched specimens. There is some difference of opinion also concerning the actual positions of the carbon atoms and the exact mechanism of the transformation from face-centered cubic to body-centered tetragonal and then to body-centered cubic structures. At any rate, it may be concluded that martensite is a solid solution of carbon in α-iron, although austenite is also almost invariably indicated by its diffraction pattern, and that the intermediate tetragonal structure accounts for hardness. The variable parameters of course could account for the very diffuse X-ray diffraction interferences as well as distortion or very small grain size.

7. **The Problem of Hardness.** Six views[36] have been presented to account for the hardness of martensite: (1) solid solution; (2) supersaturated solid solution; (3) fineness of grains; (4) distorted space lattice; (5) presence of minute particles of carbide; and (6) internal strains. These reduce to two general phenomena associated with hardness: (1) distortion and (2) slip resistance by the keying action of small particles.

Bernal[37] points out that a pure metal crystal, when stressed, yields not by cleavage or fracture but by the formation of glide planes in which layers of atoms slip over each other with little loss of energy. It is possible that in the ideal case of an absolutely pure metal with infinitely small stress it would lose no energy at all in gliding. Its behaviour would, in fact, be that of a liquid, and a pure metal crystal would only differ from a liquid by the regular ordering of its atoms. Actually, however, when a certain amount of gliding has taken place, a hardening sets in which prevents further gliding. This hardening is almost certainly due to a distortion of the lattice elements. What appears to be an exactly similar distortion is produced by the presence of foreign atoms in solid solution. (It is of course to these properties of hardening by cold working and alloying that metals owe their technical importance.) The distortion of the lattice manifests itself in a variety of ways; as well as the mechanical hardening there is always a very large increase in the electrical resistance, but what shows most clearly the nature of the change is the X-ray evidence. In a strained or impure metal crystal the reflection of a monochromatic ray in a crystal plane, instead of occurring extremely sharply over a width of a few seconds of arc, occurs more and more diffusely as the strain is increased. This is an indication that the atoms no longer lie in absolutely plane parallel layers but that there is a more or less irregular displacement of certain atoms from the average planar position. A similar but periodic displacement is produced by the temperature vibration of the atoms, and indeed on looking at an X-ray photograph of a metal which shows very blurred lines it is impossible without further information to know whether they are due to impure crystals, distorted crystals, or hot crystals. It is probable that the effects which Dr. Kapitza[37a] has found in high magnetic fields are due to a similar distortion of the lattice. It is possible that solid solutions do not represent stable states but metastable ones; that given sufficient atomic mobility, or sufficient time, all solid solutions would separate out into their constituent compounds, or form regular superstructures. From this point of view the solid solution is a mere regular form of a glass.

The *age-hardening of duralumin* and similar light alloys of aluminum has been the subject of several X-ray investigators, notably the very recent studies of Gayler and Preston[38] and of Schmidt and Wassermann.[39] The conclusion very generally reached now is that the separation of $CuAl_2$ in finely divided state has by far the largest effect, though Mg_2Si and Mg are also effective.

8. **Alloy Steels.** The success attendant upon the complete interpretation of the highly complex X-ray diffraction patterns obtained with alloy steels within the past two years has been truly amazing. A rationally scientific explanation can now be given to the properties of various alloy steels in terms of ultimate constitutions and structure. Ranges of stability of phases are defined and predictions of the constitution and properties of new alloys are non-empirically made. A very few of all the facts which X-rays have disclosed are enumerated simply as an indication of achievements and possibilities, other results being briefly noted in the tabular summary of alloys:

a. The identification in the iron-tungsten system of Fe_2W (hexagonal) and Fe_3W_2 (trigonal, 40 atoms per unit cell) and of Fe_3Mo_2 corresponding to Fe_3W_2 in the iron-molybdenum system (Fig. 46).[40]

b. Studies of the iron–chromium–carbon system and stainless steel[41] with the following conclusions:

1. Iron and chromium form a continuous series of solid solutions.
2. Phases in the Fe–Cr–C system:
   α-metal.
   γ-metal.
   Cementite $(Fe,Cr)_3$ in which chromium may rise to 15%.
   Cubic chromium carbide $(Cr,Fe)_4C$ in which chromium may be substituted by iron up to 25%.
   Trigonal chromium carbide $(Cr,Fe)_7C_3$ with iron up to 55%.
   Orthorhombic chromium carbide $(Cr,Fe)_3C_2$ with only a few percent of iron substituting.
3. In annealed ball-bearing steel the chromium is contained in cementite. "Double carbide" causing rejection, due only to unequal distribution of cementite.
4. Carbide in stainless steel is cubic chromium carbide saturated with iron (35%).
5. Steel for dies (17% nickel, 11% chromium, 2% carbon) contains trigonal chromium carbide with more than half of the chromium substituted by iron.
6. Ferro-chromium (60% Cr, 5% C) peritectic alloy of cubic chromium carbide with iron substituting partially, α-metal, and some trigonal carbide.

c. The identification in high speed steel of a true double carbide Fe_4W_2C, face-centered cubic, $a = 11.04$ A. U., containing 112 atoms per unit cell.[42]

[33] *Z. Physik*, **45**, 384 (1927).
[34] *Sci. Repts., Tohoku Imp. Univ.*, **17**, 743 (1928); *J. Study Metals*, **5**, 380 (1928).
[35] *Nature*, **122**, 475 (1928); *Z. Physik*, **53**, 696 (1929).
[36] Sauveur, *Trans. Am. Inst. Mining Met. Eng.*, **73**, 859 (1926).
[37] *Trans. Faraday Soc.*, **25**, 370 (1929).
[37a] *Proc. Roy. Soc.*, **123**, 292 (1929).
[38] *J. Inst. Metals* (preprint), **1929**, 489.
[39] *Metallwirtschaft*, **7**, 1329 (1928).
[40] Arnfelt, *Carnegie Scholarship Memoirs, Iron and Steel Inst.*, **17**, 1 (1928).
[41] Westgren, Phragmen, and Negresco, *J. Iron and Steel Inst.*, **117**, 383 (1928).
[42] Westgren and Phragmen, *Trans. Am. Soc. Steel Treating*, **1928**, 539.

d. The identification and proof of Fe_4N, important in case hardening of iron by nitrogen, with the iron on a face-centered cubic lattice, $a = 3.789$ A. U. and the nitrogen at the center.[43]

9. Crystal Structure and Magnetism. The fact that α-iron is magnetic and β-iron non-magnetic though X-rays detect no structural discontinuity between these, seems to indicate that magnetic properties are not functions of the arrangement of atoms in space. However, Persson[44] in Westgren's laboratory has recently demonstrated that the magnetic Heusler alloys (copper-manganese-aluminum) always show the X-ray diffraction lines of the β-phase. In this the basic lattice is body-centered cubic, upon which is superposed a face-centered cubic lattice of aluminum atoms with twice the dimensions of the basic lattice. Hence the unit cube contains 16 atoms, of which 12 are copper + manganese and 4 aluminum. The formula $(Cu, Mn)_3Al$ is substantiated by the X-ray results. It is further essential that the concentration of manganese must be above a limiting value in order for magnetic properties to develop. In other words the pattern for the β-phase may appear for non-magnetic specimens if manganese is insufficient. Further work will be awaited with interest.

[43] Hägg, *Nature*, Sept. 1, 1928.
[44] *Naturwissenschaften*, **16**, 631 (1928).

Tabulation of X-Ray Results on Binary Alloys

Key: 1, Systems are listed alphabetically with element first whose name begins with the letter nearest the beginning of the alphabet; e. g., Sb–Cu, antimony–copper.

2, Lattice types given for simpler cases with the symbols adopted by Ewald in his comprehensive review of crystal structure data appearing serially in *Zeitschrift für Kristallographic*.

- A-1 Face-centered cubic
- A-2 Body-centered cubic (tungsten)
- A-3 Hexagonal close-packed
- A-5 Diamond cubic
- B-1 Simple cubic (NaCl)
- B-2 Body-centered cube (cesium chloride)
- B-3 Diamond cubic (zinc blende)
- B-4 Hexagonal wurtzite type
- B-8 " NiAs type
- B-9 " HgS type
- B-12 BN type
- C-1 Cubic, CaF_2 type
- C-2 " pyrites type
- C-6 Layer lattice, CdI_2 hexagonal
- C-7 Hexagonal, MoS_2 type
- C-11 Nearly cubic, CaC_2 type
- C-12 $CaSi_2$ type
- C-14 $MgZn_2$ type
- D-2 $CoAs_2$ type.

3, References are given by numbers referring to appended bibliography.

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System	Compound	Solid Solution	Lattice Type	Dimension	No. of Atoms	References
Al–Sb	AlSb		B-3	$a = 6.10$		77, 158
Al–As	AlAs		B-3	$a = 5.63$		77, 140
Al–Cu	(See Figure 48)					4, 15, 20
α		100% Cu	A-1	$a = 3.611$		25, 35, 71
		92.7% Cu		$a = 3.652$		100, 118
β	Cu_3Al (high temp.)		?			155, 176
			Cubic		52	
γ'		84% Cu		$a = 8.701$		
		75% Cu		$a = 8.656$		
δ	$CuAl_2$		A-5	$a = 6.052$	4	
				$c = 4.88$		
				$c/a = 0.81$		
ϵ			A-1	a decreases as % Cu increases		
Al–Mg		0% Al	A-3	$a = 3.17$		
				$c = 5.17$	25	
		7.3%	A-3	$a = 3.151$		
				$c = 5.23$		
		91.2% Al	A-1	$a = 4.106$		
		100% Al	A-1	$a = 4.05$		
Al–Ni	AlNi		B-2	$a = 2.82$		25, 78
Al–N	AlN		B-4	$a = 3.113$		150
				$c = 4.981$		
				$c/a = 1.60$		
Al–P	AlP		B-3	$a = 5.45$		77
Al–Ag	(See Figure 48)					
α		0% Al	A-1	$a = 4.079$		60, 192
		19% Al		$a = 4.056$		
β'	Ag_3Al		Cubic	$a = 6.920$	52	
γ		27% Al	A-3	$a = 2.865$		
		40% Al		$c = 4.653$		
				$a = 2.879$, $c = 4.573$		
δ		Ag in Al very small	A-1	$a = 4.42$		
Al–Zn		0% Zn	A-1	$a = 4.043$		164
		20% Zn	A-1	$a = 4.034$		
		20–95% Zn	A-1 + A-3			
		95–100% Zn	A-3			
Sb–Co	CoSb		B-8	$a = 3.87$		77, 109
				$c = 5.19$		
				$c/a = 1.34$		
Sb–Cu	Cu_3Sb (See Figure 48)		A-3	$c/a = 1.572$		103, 199A
Sb–Cr	CrSb		B-8	$a = 4.11$		77, 109
				$c = 5.46$		
				$c/a = 1.328$		
Sb–Ga	GaSb		B-3	$a = 6.09$		75, 77
Sb-In	InSb		B-3	$a = 6.45$		77
Sb–Fe	FeSb		B-8	$a = 4.06$		77, 82
				$c = 5.13$		
				$c/a = 1.264$		
Sb–Mn	MnSb		B-8	$a = 4.12$		77
				$c = 5.78$		
				$c/a = 1.404$		
Sb–Ni	NiSb		B-8	$a = 3.94$		1, 104, 109
				$c = 5.14$		
				$c/a = 1.304$		
Sb–Pd	PdSb		B-8	$a = 4.070$		186
				$c = 5.582$		
	$PdSb_2$		C-2	$a = 6.43$		
Sb–Ag	Ag_3Sb (See Figure 48)		Hex.	$c/a = 1.572$		122, 199A
Sb–Sn			B-3	$a = 6.13$		77
Sb–Tl		Four phases				
		1. Tl	A-3	$a = 3.449$		17, 75, 77, 163
		2. 7% Sb	A-1	$a = 4.842$		
	Tl_7Sb_2	3.	Complex cubic	$a = 11.59$		
		4. Sb	A-7	$a = 4.50$		
As–Co	CoAs		D-2	$a = 8.189$		77, 142, 144
As–Cr	CrAs		Hex.	$a = 3.76$		109
				$c = 5.32$		
As–Ga	GaAs		B-3	$a = 5.64$		77
As-Fe	$FeAs_2$		Rhombic	$a = 6.35$		4, 82, 106
				$b = 4.86$		
				$c = 5.80$		
As–Mg	Mg_3As_2		Cubic new type	$a = 6.10$	2	141
As–Mn			Hex.	$a = 3.716$		145
				$c = 5.704$		
As–Ni	NiAs		B-8	$a = 3.57$		2, 104, 109
				$c = 5.10$		
				$c/a = 1.43$		
As–Pt	$PtAs_2$		C-2	$a = 5.92$		105, 170
As–Zn	Zn_3As_2		Cubic new type	$a = 5.81$	2	141
Ba–Se	BaSe		B-1	$a = 6.59$		77, 180, 181
Ba–S	BaS		B-1	$a = 6.37$		77, 93
Ba–Te	BaTe		B-1	$a = 6.99$		75, 183
Be–Se	BeSe		B-3	$a = 5.13$		75, 205
Be–S	BeS		B-3	$a = 4.857$		77, 204
Be–Te	BeTe		B-3	$a = 5.61$		75, 205
Bi–Tl	TlBi		B-2	$a = 3.98$		75, 77
B–Fe	$(Fe_2B)x$		Tetragonal	$a = 5.078$	4	200
				$c = 4.223$		
B–N	BN		B-12	$a = 2.51$		77, 91, 99
				$c = 6.69$		
				$c/a = 2.66$		
Cd–Se	CdSe		B-3	$a = 6.04$		77
			B-4	$a = 4.30$		75, 205
				$c = 7.02$		
				$c/a = 1.637$		

System	Compound	Solid Solution	Lattice Type	Dimension	No. of Atoms	References
Cd–Ag α		S. s. Cd in Ag 31% Cd	A-1	a = 4.14		13, 15, 138, 139
β		AgCd and s. s. Cd in AgCd				
		44% Cd	A-1			
		47% Cd	B-2	a = 3.32		
		51% Cd	B-2	a = 3.34		
	AgCd		Hex.	a = 3.01		
γ	Ag_5Cd_8		Cubic	a = 9.99	52	
			Hex.	c/a = 1.58	2	
ϵ		74.25% Cd		a = 3.02		
		66.1–89.63% Cd		a = 3.04–3.09		
η		S. s. Ag in Cd 95% Cd		a = 2.95		
				c/a = 1.89		
Cd–S	α-CdS		B-4	a = 4.14		39, 77, 188
				c = 6.72		
				c/a = 1.62		
	β-CdS		B-3	a = 5.82		77, 188
Cd–Te	CdTe		B-3	a = 6.464		203, 205
Ca–C	CaC_2		C-11	a = 5.74		61
Ca–Se	CaSe		B-1	a = 5.912		59, 77
Ca–Si	$CaSi_2$		C-12	a = 10.4	2	33
Ca–S	CaS		B-1	a = 5.68		58, 77, 117
Ca–Te	CaTe		B-1	a = 6.34		75, 77
C–Cr	Cr_4C		A-1	a = 10.638	24	197
	Cr_7C_3		Hex.	a = 13.98	8	
				c = 4.523		
				c/a = 0.324		
	Cr_3C_2		Orthorhombic	a = 2.821	4	
				b = 5.52		
				c = 11.46		
		15–25% C three phases coexist				
C–Mo		30% C	A-3	a = 2.993		26, 198A
		C atoms go in between lattice atoms		a increases with % C		
C–Ta	TaC		B-1	a = 4.427		7, 26, 77
C–Ti	TiC		B-1	a = 4.60		7, 26
C–W		30% C	Hex.	a = 2.986		6, 23, 22, 24, 27, 198
				c/a = 1.573		
	WC	50% C	Almost A-3	a = 2.901		
				c/a = 0.975		
	W_2C		Rhombic	a = 3.49	1	
C–V	VC		B-1	a = 4.30		26
C–Zr	ZrC		B-1	a = 4.76		7, 26
Cr–Fe		Continuous series	A-2	a = 2.861 to 2.878		199B
Cr–Ni		0–63% Cr.	A-1	2.8% distortion		32, 164, 32A
		63–100% Cr	Cr lattice			
Cr–Se	CrSe		B-8	a = 3.59		109
				c = 5.80		
				c/a = 1.62		
Cr–S	CrS		A-8	a = 3.44		109
				c = 5.67		
Co–Fe		0–80% Co	Fe lattice			5
Co–Se	CoSe		B-8	a = 3.59		77, 109, 110A
				c = 5.27		
				c/a = 1.468		
	$CoSe_2$		C-2	a = 5.854		
Co–S	CoS		B-8	a = 3.37		1, 110
				c = 5.14		
				c/a = 1.52		
	CoS_2		C-2	a = 5.64		
Co–Te	CoTe		B-8	a = 3.89		77
				c = 5.36		
				c/a = 1.378		
Cb–N	CbN		B-1	a = 4.41		26
Cu–Au	CuAu		Tetragonal face centered	a/c = 1.078		11, 15, 79, 101, 102, 113, 118, 182, 189
		24.30% Au	A-1	a = 3.731		
		50.41		a = 3.879		
		74.24		a = 3.976		
Cu–Ni		Continuous series	A-1			15, 60, 94, 173, 189
Cu–Pd		0–38% Pd	A-1			95, 101, 102
		0% Pd		a = 3.620		
		19.4% Pd		a = 3.655		
		36.4% Pd		a = 3.724		
		38–39.9% Pd	Cu + Pd lattices			
	PdCu	40–50% Pd	PdCu lattice			
		45.5% Pd		a = 2.988		
		50–100% Pd	A-1			
		54.4% Pd		a = 3.750		
		70.2% Pd		a = 3.812		
		100% Pd		a = 3.897		
Cu–Se	Cu_2Se		C-1	a = 5.749		59, 89
Cu–Si				Cu lattice enlarged at low Si %		60
Cu–Ag		0–9.2% Cu	A-1	a = 4.06–4.03		64, 173
		9.3–96.3% Cu	Ag + Cu lattices			
		96.4–100%	A-1			
Cu–S	CuS		Complex	a = 6.66		1, 18
			Hex.	c = 9		
	Cu_2S		C-1	a = 5.59		
Cu–Sn α	(See Figure 48)	0–10% Sn	A-1	a = 3.61–3.65	4	15, 28, 35, 53, 103, 190, 199
β		(15% Sn)	A-2	a = 2.972	2	
δ-γ	Cu_4Sn ($Cu_{41}Sn_{11}$)	(20% Sn)	A-1	a = 17.91	416	
ϵ	Cu_3Sn	(25% Sn)	A-3	a = 2.775		
				c/a = 1.568		

System	Compound	Solid Solution	Lattice Type	Dimension	No. of Atoms	References
η	Cu_6Sn_5	(60% Sn)	B-8	$a = 4.190$ $c = 5.086$		
Cu–Zn	(See Figure. 48)					
α		100% Cu	A-1	$a = 3.610$		5, 15, 19, 25, 35, 36, 98, 121, 137, 156, 165, 194, 195
		67.8% Cu	A-1	$a = 3.688$		
β	CuZn	53.1% Cu	B-2	$a = 2.945$	52	
γ	Cu_5Zn_8	38.3% Cu	Cubic with 1 atom in 27 removed	$a = 8.850$		
		32.3% Cu		$a = 8.887$		
ϵ		19.7% Cu	A-3	$c/a = 1.55$ $a = 2.746$		
		13.9% Cu		$a = 2.761$		
			A-3	$c/a = 1.85$		
η		3.5% Cu		$a = 2.666$		
		0% Cu		$a = 2.662$		
Ga–P	GaP		B-3	$a = 5.44$		77
Au–Pd		Continuous series	A-1			95
Au–Ag		Continuous series	A-1			15, 95, 124, 126, 129, 130, 131, 190
Au–Sn	AuSn		B-8	$a = 4.307$ $c = 5.496$		
Au–Zn α		100% Au	A-1	$a = 4.073$ increases with % Zn		159, 194, 195
	AuZn	69.8% Au	B-2	$a = 3.146$	52	
γ		63.1% Au	Cubic	$a = 9.268$		
		58.9% Au		$a = 9.223$	32	
γ'		49.8% Au	Cubic	$a = 7.880$		
ϵ		32.5% Au	A-3	$c/a = 1.56$ $a = 2.809$ $c = 4.377$		
		27.7		$a = 2.809$ $c = 4.369$		
η		5% Au	A-3	$c/a = 1.83$ $a = 2.674$ $c = 4.887$		
H–Pd	Pd_2H	Enlargement of Pd lattice		$a = 3.97$		46, 115, 120, 125, 127, 202
Ir–Os	IrOs				2	3
Fe–Mo	Fe_3Mo_2		Trigonal	$a = 4.743$ $c = 25.63$	40	15, 29
Fe–Ni		0–74% Fe	Ni lattice			5, 111, 128, 147, 32A
		74–100% Fe	Fe lattice			
Fe–N	Fe_4N		Cubic	$a = 3.86$		50, 49, 80, 81, 148
	Fe_2N		Hex.	$a = 2.743$ $c/a = 1.59$		
Fe–Se	FeSe		B-8	$a = 3.61$ $c = 5.87$ $c/a = 1.626$		1
Fe–S	FeS		B-8	$a = 3.43$ $c = 5.75$ $c/a = 1.66$		38, 69, 68
	Fe_2S pyrite		C-2	$a = 5.404$		1, 38A, 40, 104
	Markasite		Rhombic	$a = 6.79$ $b = 4.45$ $c = 5.42$		106, 107 109, 170
Fe–Te			Hex.	$a = 3.800$ $c = 5.651$		145
Fe–W		Two intermediate phases				15, 29
	Fe_2W		Hex.	$a = 4.727$ $c = 7.704$	4	
	Fe_3W_2		Trigonal	$a = 4.731$ $c = 25.76$	40	
Fe–Zn	Fe_3Zn_{10}		Cubic	$a = 8.93$	52	149
	$FeZn_7$		A-3	$a = 2.788$ $c = 4.481$	2	
	$FeZn_3$					
Pb–Mg	Mg_2Pb		C-1	$a = 6.76$		470, 173
		0–66% Mg	Pb + $PbMg_2$ lattices			
		66–100% Mg	$PbMg_2$ + Mg lattices			
Pb–Se	PbSe		B-1	$a = 5.93$		44, 56, 119
Pb–Te	PbTe		B-1	$a = 6.444$		75, 77
Pb–Sn		0–3.6% Sn	A-1	$a = 4.942$–4.931		164
		10–95% Sn	Pb + Sn lattices			
		95–100% Sn	Sn lattice			
Pb–Tl		35% Pb	Pb lattice	$a = 4.871$		83, 84, 132
Mg–Se	MgSe		B-1	$a = 5.45$		75, 77
Mg–Si	Mg_2Si		C-1	$a = 6.39$		157
Mg–S	Mg-S		B-1	$a = 5.19$		93, 77, 201
Mg–Te	MgTe		B-4	$a = 4.52$ $c = 7.33$ $c/a = 1.622$		7, 208
Mg–Sn	Mg_2Sn		C-1	$a = 6.77$		161, 173
Mg–Zn	$MgZn_2$		C-14	$a = 5.15$		72
Hg–Se	HgSe		B-3	$a = 6.068$		75, 88, 106A, 206
Hg–Ag	Ag_3Hg_4					191
Hg–Te	HgTe		B-3	$a = 6.440$		77, 88, 106A, 203, 205
Mo–S	MoS_2		Hex	$a = 3.15$ $c = 12.30$ $c/a = 3.90$		10, 57, 63, 90
Mo–W		Continuous series	A-2			7, 9, 15
Ni–Se	NiSe		B-8	$a = 3.66$ $c = 5.33$ $c/a = 1.456$		1, 110A
	NiS_2		C-2	$a = 6.022$		

System	Compound	Solid Solution	Lattice Type	Dimension	No. of Atoms	References
Ni–S	NiS_2		C-2	$a = 5.74$		110
Ni–Te	NiTe		B-8	$a = 3.95$ $c = 5.36$ $c/a = 1.357$		77
Ni–Sn			Hex.	$a = 4.081$ $c = 5.174$		145
Ni–W	Ni_6W NiW					25
N–Sc	ScN		B-1	$a = 4.44$		26
N–Ta	TaN		B-4	$a = 3.05$ $c/a = 1.62$		8
N–Ti	TiN		B-1	$a = 4.40$		8, 26
N–V	VN		B-1	$a = 4.28$		26
N–Zr	ZrN		B-1	$a = 4.63$		8, 26
Os–Te	$OsTe_2$		C-2	$a = 6.369$		187
Pd–Se	$PdSe_2$		Like CdI_2	$a = 3.724$ $c = 5.062$		187
Pd–Ag		Continuous series	A-1			115, 124, 126, 131
Pd–Te	$PdTe_2$		Like CdI_2	$a = 4.028$ $c = 5.118$		187
	PdTe		B-18	$a = 4.127$ $c = 5.663$		
Pt–Se	$PtSe_2$		C-2	$a = 6.428$		187
Pt–Te	$PtTe_2$		Like CdI_2	$a = 4.010$ $c = 5.201$		187
Pt–Sn			Hex.	$a = 4.103$ $c = 5.428$		145
Ru–Se	$RuSe_2$		C-2	$a = 5.921$		187
Ru–Te	$RuTe_2$		C-2	$a = 6.360$		187
Se–Sr	SrSe		B-1	$a = 6.23$		77
Se–Ti	$TiSe_2$		C-6	$a = 3.53$ $c = 6.00$ $c/a = 1.700$		77
Se–Zn	ZnSe		B-3	$a = 5.66$		59, 75, 77, 205
Se–Zr	$ZrSe_2$		C-6	$a = 3.79$ $c = 6.18$ $c/a = 1.631$		8
Si–Zr	$ZrSi_2$		Rhombic	$a = 3.72$ $b = 14.61$ $c = 3.67$		177
Ag–Sn	(See Figure 48)					199A
Ag–Zn α	(See Figure 48)		A-1	a decreases with % Zn		15, 194, 195
β	AgZn	61.75% Ag	B-2 Cubic	$a = 3.156$	52	
γ		49.7% Ag	A-3	$a = 9.327$ $c/a = 1.55$–1.58		
ϵ		39.5% Ag		$a = 2.818$ $c = 4.456$		
		21.9% Ag		$a = 2.815$ $c = 4.382$		
η		100% Zn	A-3	$c/a = 1.85$ $a = 2.662$ $c = 4.941$		
Sr–Te	SrTe		B-1	$a = 6.65$		75, 77
Sn–S	SnS_2		C-6	$a = 3.62$ $c = 5.85$ $c/a = 1.616$		
Te–Sn	SnTe		B-1	$a = 6.285$		77
Te–Ti	$TiTe_2$		C-6	$a = 3.79$ $c = 6.45$ $c/a = 1.702$		77
Te–Zn	ZnTe		B-3	$a = 6.09$		77, 203, 205

The Electrolytic Preparation of Alloys of Barium and of Strontium

By Kenneth W. Ray*

Very few alloys of either barium or strontium have ever been studied. These metals are difficult to prepare and are expensive. The fact that molten barium and strontium readily form oxides, hydrides, nitrides, and carbides, makes the melting and pouring of these metals difficult. Also, since these metals react with practically all of the common gases, such as oxygen, hydrogen, nitrogen, carbon dioxide and others, it is impractical to carry on such operations in an inert atmosphere unless argon or helium is available.

On account of the scarcity of these metals due to the difficulties of preparation, their alloys are seldom made directly, that is, by simply melting the metallic barium or strontium with the other metal. Other methods, however, have been developed. H. Gautier[1] prepared strontium-zinc and strontium-cadmium, as well as the corresponding barium alloys, by heating a mixture of the anhydrous chlorides of these metals with sodium. C. J. Kroll[2] suggests a method of preparing alkali earth alloys of lead, aluminum, copper, etc., by fusing an alkali earth salt with the sodium alloy of the metal wanted. Using this method, K. Jellinek and G. Tomoff[3] heated sodium lead alloys with the alkali earth chlorides and obtained lead-barium, lead-strontium, and lead-calcium alloys. Another method of preparing lead alloys with the alkali earth metals has recently been patented by G. J. Kroll,[4] in which metallic lead is heated with an alkaline earth carbide.

However, an electrolytic method seems to be the most convenient for the preparation of barium and strontium alloys. C. E. Acker[5] was one of the first to demonstrate the convenience of preparing alloys of active metals by this method. He prepared sodium-lead alloys on a commercial scale by electrolyzing a bath of fused sodium chloride using a cathode of molten lead. The sodium-lead alloys were then decomposed by water or steam to give sodium hydroxide. In an attempt to prepare metallic magnesium, S. A. Tucker and F. L. Gouard[6] prepared alloys of aluminum and magnesium, and of copper and magnesium by the electrolysis of fused magnesium chloride with molten aluminum and molten copper, respectively, as the cathode. Also, G. O. Steward and Franz von Kugelen[7] patented a method of preparing barium alloys by the electrolysis of a molten barium salt with a cathode of a fusible metal.

W. A. Cowan, L. D. Simpkins and G. O. Hiers[8] have described the preparation of Frary metal, a calcium-barium-lead alloy. This alloy is made on a commercial scale by electrolyzing a fused mixture of barium and calcium chlorides with molten lead as cathode. The alloy is used as a bearing metal.

Among the other investigators who have used the electrolytic method for the preparation of alloys, K. Jellinek and J. Wolff[9] have done some important work from the standpoint of the alloys of the alkali earth metals. These investigators studied the equilibrium conditions existing between the alkali and the alkali earth metals and their salts. The experiments were made in a fire-clay crucible which had an electrode cemented in the bottom. A metal consisting of either lead, tin, bismuth or antimony was placed on this electrode, which served as the cathode. A mixture of an alkali and an alkali earth chloride was then placed in the crucible, and the fused salts electrolyzed. In this way the barium, the strontium and the calcium alloys of each of lead, antimony, zinc, bismuth and tin were prepared. However, none of these alloys were pure since they contained from 0.2 to 1.1 percent of sodium or potassium. Furthermore, these investigators did not attempt to free the alloys of the sodium and the potassium, nor were the properties of the alloys studied.

A large number of alloys of the alkali earth metals have never been prepared. This is especially true of the alloys of barium and strontium. The electrolytic method seems to be the easiest and most convenient one for the preparation of the alloys. Yet there is nothing in the literature to indicate just which of the alloys can be prepared by this method. Also important information concerning the details of the method is not given. Data concerning the composition of the baths, the current efficiencies that can be obtained, the maximum percent of barium or strontium that can be deposited in the alloy etc., are very meager or entirely lacking. Furthermore, it seems possible that metallic crucibles could, in some cases, be used in place of those made of fire clay. This would simplify the form of apparatus necessary.

The purpose of this work was to determine what alloys of barium and strontium could best be prepared electrolytically. An attempt was also made to test and compare the various types of apparatus and the composition of the baths.

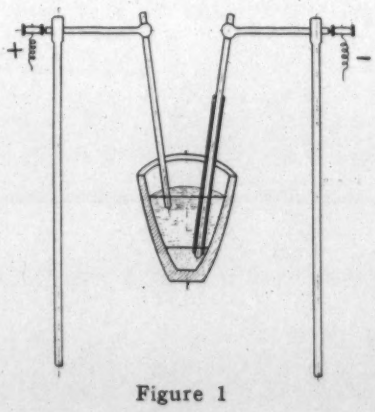

Figure 1

Three different types of apparatus were used during this investigation. A diagram of the first is shown in Figure 1. It consisted of a porcelain crucible of 250 cc. capacity, in the bottom of which was about 100 grams of the metal to serve as cathode, and on this, the salt mixture which was to be electrolyzed. The anode consisted of an arc carbon rod 1 cm. in diameter and 15 cm. in length. Electrical contact was made with the cathode metal by means of another arc carbon insulated from the salt bath by inserting it in a close fitting tube of fused quartz. The crucible and contents were heated in an electrically heated crucible furnace. After the salt bath and the metal had become molten electrolysis was begun. Chlorine (and oxygen?) was evolved at the anode and metallic barium or strontium was deposited in the cathode metal.

This apparatus was not entirely satisfactory. The barium or strontium in the cathode alloy reacted with the carbon rod forming a small amount of carbide and disentegrating the rod. A part of the carbides formed remained in the alloy and a part went into the salt bath. Metal rods, both insulated and non-insulated, were used instead of the carbon (cathode) rod, but most of these dissolved to come extent in the alloy. The crucible was removed from the furnace and the salts and the alloy poured into a mold while hot, yet enough of the salts usually adhered to the crucible to cause it to crack during cooling. Furthermore, the quartz insulation tube became brittle and cracked, especially at the lower end, after about ten to twenty hours of use. This might have been due to its reaction with the barium or strontium metal or oxide. Glass insulation tubes were worthless at the temperatures employed.

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[1] *Compt. Rend.*, **133**, 1005 (1901), and **134**, 1054 (1902).
[2] Brit. patent 164,608 (1920).
[3] *Z. phys. Chem.*, **111**, 234 (1924).
[4] U. S. Patent 1,707,059 (Mar. 26, 1929).
[5] *Trans. Amer. Electrochem. Soc.*, **1**, 165 (1902).
[6] *Ibid.*, **17**, 249 (1910).
[7] U. S. patent 900,962 (Oct. 13, 1909).
[8] *Trans. Amer. Electrochem. Soc.*, **40**, 27 (1921).
[9] *Z. anorg. Chem.*, **146**, 329 (1925).

The second type of apparatus used was similar to that employed by K. Jellinek and G. Wolff (previous reference). See Figure 2. It consisted of a fire-clay crucible, through the bottom of which a wrought steel bolt had been cemented to serve as an electrical connection to the cathode metal. This crucible rested upon a steel plate, and the whole was contained in a gas fired furnace. The cathode metal, the salt to be electrolyzed and the anode were the same as in the first apparatus. This apparatus was no better than the first one. It proved difficult to prevent the metal connection which was cemented through the bottom of the crucible from becoming loose and permitting the alloy to leak out. In some cases, a part of the iron connection also dissolved in the cathode alloy, and contaminated it. Furthermore, the steel plate and connection oxidized very badly in the fire and finally burned in two. By employing heat resisting alloys this apparatus would probably have given better service.

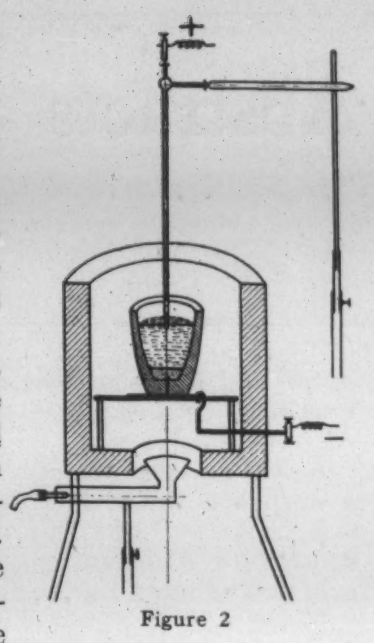


Figure 2

The third form of apparatus consisted of a metallic crucible containing the molten metal and fused salt. The anode was the same as in the previous cases while the crucible itself served as the cathode. Contact was made with the crucible by having it rest in an iron ring which was connected with the negative terminal of the electric circuit. The crucible and contents were heated directly by a Fisher burner. This apparatus was much better than either of the others as far as convenience and simplicity were concerned. The disadvantage was that the metal of the crucible, in some cases, dissolved in the alloys prepared. Crucibles of nickel, of wrought iron, and of chromium-plated iron were tried. The iron crucible lasted well and did not greatly contaminate the alloys when used for preparing alloys of lead and of bismuth. The alloys formed contained less than 0.2% of iron. Iron crucibles were also used for preparing alloys of cadmium and tin, but here the solubility of the iron in the alloy was much greater, and an iron crucible could be used only when the temperature was kept low. Even when made at low temperatures, the alloys contained appreciable amounts of iron. Nickel crucibles seemed to be much less serviceable than those of iron. Iron crucibles that had been heavily plated inside with chromium served for the preparation of alloys of bismuth, of tin and of lead. The chromium plated crucible gave good service and did not seem to contaminate the alloys formed.

A large number of salts were tried in order to find a bath suitable for electrolysis. Both barium chloride and strontium chloride had too high a melting point to be satisfactory alone. The melting points could be sufficiently lowered by mixing with other salts. Following is a list of some of the salt mixtures used and their melting points:

"Physikalisch-Chemische Tabellen" Landolt-Borstein. Fifth Edition, 1923, Berlin

Compositions are given in molecular percentages.

KCl	45	$BaCl_2$	55	646° C.
NaCl	39	$BaCl_2$	61	654° C.
KBr	52	$BaBr_2$	48	613° C.
$BaCl_2$	90	BaI_2	8	700° C.
LiCl	30	$BaCl_2$	70	511° C.
KCl	28	$SrCl_2$	72	596° C.
NaCl	50	$SrCl_2$	50	565° C.
SrO	11.4	$SrCl_2$	88.6	797° C.
$SrCl_2$	11	SrF_2	89	753° C.
NaBr	61	$SrBr_2$	39	486° C.

When sodium or potassium chloride was used the melting point of the salt mixture was satisfactory but small amounts of these metals were deposited in the alloys formed. Also when these baths were electrolyzed at high temperatures (800–900°) the salts volatilized very rapidly.

The mixture of the alkali earth chloride and iodide had a fairly low melting point, and an alloy free from sodium or potassium was obtained, but only the iodide salt was decomposed and iodides are expensive. Small amounts of both barium and strontium oxides will dissolve in the fused chlorides, but the melting point of these mixtures is high. After they had been used for sometime, these baths became black and viscous and were unsatisfactory. Baths consisting of either barium or strontium bromide alone served fairly well, but volatilized rapidly at high temperatures. The best results were obtained in the preparation of low melting alloys by electrolyzing a mixture of the alkali and the alkali earth chlorides. The sodium or potassium in the alloy was removed by remelting the alloy under a bath of pure barium or strontium chloride. The remelting also seemed to clean the alloy of other undesirable impurities such as carbides, oxides, etc., and to make the alloy more firm and free from gas holes and inclusions.

Alloys of barium and of strontium with the following metals have been prepared: tin, lead, zinc, cadmium, bismuth, antimony and aluminum. Much difficulty was experienced in the preparation of the aluminum alloys due to the fact that the salt mixtures had a higher specific gravity, in some cases, than the molten aluminum, and the metal thus had a tendency to rise to the surface. Attempts to produce a barium-copper alloy have met with very little success. Further work is being done on the preparation of the alloys with aluminum and copper.

A high current density was employed. From 12 to 20 amperes were used with a cathode surface of about 12 to 15 sq. cm. The current density at the anode was about the same as that at the cathode and averaged about one to one and one-fourth amperes per sq. cm. The voltage varied from 5 to 4 volts. The high value was obtained at high temperatures when the anode became more or less "passive" and the current seemed to arc from the anode to the molten salt through the layer of evolved gases.

The current efficiencies obtained were quite high at the beginning of the electrolysis, but decreased rapidly as the amount of the alkali earth metal in the alloy increased. Current efficiencies of 60–80% were common in obtaining an alloy of 95% Sn-5% Ba, etc., but after the amount of barium had been increased to 20 or 25% the efficiency had dropped to a very low figure, 5 to 10% of the theoretical. The efficiency continued to drop as the amount of the alkali earth metal increased until finally it approached zero and a richer alloy could not be produced under the existing conditions of temperature, current density, bath composition, etc. Also at high concentrations of barium or strontium the alloys became porous and spongy. They seemed to disintegrate, and small particles became detached from the remainder and came to the surface and burned. Alloys with more than 27% barium in antimony, 20% strontium in tin, 28% barium in tin, and 16% barium in bismuth were difficult to obtain. Alloys of aluminum with more than 2 or 3% barium were not obtained.

The properties of the alloys formed were very interesting. All of them were much harder than the original metal, and they possessed a much higher melting point. In practically all cases evidences of the presence of intermetallic compounds were found. Most of the alloys were coarsely crystalline, more brittle and less malleable than the original metal, and tarnished in air very rapidly. Most of them also decomposed cold water with the evolution of hydrogen. The properties of these alloys are being studied further and will be reported as the progress of the work warrants.

Correlated Abstracts

Dr. Gillett, the editorial staff and specially selected contributors will prepare abstracts reviewing the work recently reported pertaining to certain subjects. These reviews will take into consideration the work of a number of workers. The current literature will be covered in the Abstracts of Current Metallurgical Literature.

The Need for Information on Notch Propagation

Everyone knows how readily a hard, brittle, material like glass will break if the glass is lightly scratched, as with a diamond point. If one wishes to break a bar of metal, he may file a notch in it and bend it back and forth; with a hard metal, few bends are required to fracture it, while with a soft, tough metal, more bends are required.

Under repeated stress, under shock, and probably even under long-continued static load, notches, scratches, sharp corners and fillets of small radii are all dangerous. Even a smoothly ground surface is detectably weaker under repeated stress than a polished one. The effect of notches, or their equivalent, is to increase the local stress very greatly at the base of the notch. Mathematically, at the apex of an infinitely sharp notch, i. e., a crack, any applied stress is so multiplied as to be infinite, and the crack should propagate instantly. Practically, in a ductile metal, when the stress at the base of the notch reaches the yield point, the metal deforms, the notch becomes less sharp, and the stress is thus automatically reduced. If the stress is reduced below the tensile strength of the metal, the crack will stop. If the metal cannot deform sufficiently to reduce the stress below the tensile strength, the crack will advance, the rate depending on the applied stress, the sharpness of the notch and the properties of the material.

If the metal is not homogeneous but contains both soft and ductile, and hard and brittle constituents, the effect of one or the other may predominate. Fortunately, the increase of stress due to a notch is not as bad in engineering alloys as the mathematical theory would predict. Gough[1] points out that the theoretical increase of stress will only occur if the material has no plasticity at all, but is fully elastic up to the breaking point.

Haigh[2] says that users of mild steel for ships and bridges are inclined to feel that "fatigue is a timid creature that seldom ventures outside the laboratory." Nevertheless, any city street will show plenty of automobile spring leaves, broken in fatigue at the bolt-holes, while the failures of shafts at key-ways, of rails by transverse fissures starting from tiny internal cracks and of heat-treated parts at hardening cracks, all testify to the real dangers of stress-raisers- notches, poor fillets, etc.

Workers in the fatigue of metals soon find that even with ductile metals, endurance limits are only correctly determined on smoothly polished specimens with large fillets. The harder the metal the greater the danger from the stress-raisers. Many pages could be filled with references to the work of H. F. Moore, R. R. Moore, Gough, Haigh, McAdam and many others who have studied the problem. One classic investigation in this field was that of Thomas,[3] and Moore[4] has recently studied the propagation of cracks in car axles.

McAdam[5] and Speller[6] have clearly shown that corrosion creates surface notches, which set like any notch in raising the stress, and that simultaneous corrosion and repeated stress are even more damaging than corrosion followed by repeated stress, since the stress increases the rate of corrosion.

Haigh[7] considers the case of (a) a solid plate, (b) a plate with a small hole drilled in it in service under a calculated steady external stress of 20,000 lbs./sq. in. and a superimposed alternating stress of 10,000 lbs./sq. in., when this service is to be met by a mild steel and by a harder, heat-treated steel.

He takes the properties of the two steels as, for example:

	Hard Steel	Mild Steel
Tensile strength, lbs./sq. in.	120,000	60,000
Yield point, lbs./sq. in.	100,000	42,000
Endurance limit for completely reversed alternating stresses, lbs./sq. in.	± 60,000	±36,000

According to Haigh, if there is no hole in the plate, either the hard or the mild steel will serve. The former will not crack till a steady stress of 60,000 lbs./sq. in. and an alternating stress of 30,000 lbs./sq. in. are applied. The mild steel will not crack, but will start to yield when a steady stress of 28,000 lbs./sq. in. and on alternating stress of 14,000 lbs./sq. in. are applied. If holes or notches are absent, the hard steel has much the greater factor of safety.

But on the other hand, if a hole is present, the situation is reversed, the hard steel will crack under the assumed service loads of 20,000 lbs./sq. in. steady stress and 10,000 lbs./sq. in. alternating stress, while the mild steel, in the presence of the hole, will fail, this time by cracking, not by yielding, only at 24,000 lbs./sq. in. in steady stress plus 12,000 lbs./sq. in. alternating stress.

Of course, mild steel is not a cure-all, since boiler failure due to cracks resulting from corrosion notches are well known,[8] yet the remedy in such cases is not merely changing to a harder steel, but either to prevent corrosion or to use a corrosion resisting steel so as to avoid formation of notches.

While the effect of a notch in service involving shock or impact is well known, and its effect in service involving repeated stress is also becoming well known, there are cases where in service not normally considered to involve impact or fatigue, material that is ostensibly ductile may fail from notch propagation.

Chain links in service acquire a severely cold-worked, brittle skin in which sharp cracks form readily. These cracks may propagate through the underlying ductile metal and make the whole link break in a brittle fashion.[9] If the brittle skin is removed, the link then acts as a ductile metal is supposed to.

Similarly a chromium plated brass wire, with a thick, brittle coating, will snap when bent in the fingers but if the plating is dissolved off, the wire itself may be wrapped around the finger.

Cyanide cased, water quenched steel will snap readily when subjected to stress,[10] although the core, after removal of the case, is satisfactorily ductile. The lack of ductility of the case plus core is ascribed to intertwining of grains of case and core in the region where carburizing or nitriding ceases in such fashion that a crack started in the case is propagated through the core.

If the case of a case-hardened piece is very brittle,[11] it is easy for a fatigue failure to start at the surface no matter how strong and tough the core may be. Spalling of gears may sometimes

[1] H. J. Gough, "The Fatigue of Metals," **1924**, page 94.

[2] B. P. Haigh, "The Relative Safeties of Mild and High-Tensile Alloyed Steels under Alternating and Pulsating Stresses," *Chem. & Ind.* (*Jour. Soc. Chem. Ind.*), **48**, 23 (1929). See also similar comments in McAdam's 1928 A. S. M. E. paper, *Translations of the A. S. M. E.*, Jan.–Apr., 1929, pages 45–58.

[3] W. H. Thomas, "Effect of Scratches and of Various Workshop Finishes on the Fatigue Strength of Steel," *Engineering* (London), **116**, 444, 483 (1923).

[4] H. F. Moore, "A Study of Fatigue Cracks in Axles," *Forging-Stamping-Heat Treating*, **13**, 447 (1921).

[5] D. J. McAdam, Jr., "Some Factors Involved in Corrosion and Corrosion-Fatigue of Metals," *Proc. A. S. T. M.*, **28**, (2), 117 (1928). See also many other publications by McAdam.

[6] F. N. Speller, I. B. McCorkle and P. F. Mumma, "Influence of Corrosion Accelerators and Inhibitors on Fatigue of Ferrous Metals," *Proc. A. S. T. M.*, **28** (2), 159 (1928).

[7] B. P. Haigh, see ref. 2.

[8] S. W. Farr and F. C. Straub, "The Cause and Prevention of Embrittlement of Boiler Plate," *Proc. A. S. T. M.*, **26** (2), 52 (1926).

[9] B. J. Gough and A. J. Murphy, "Causes of Failure of Wrought Iron Chain and Cable," *Proc. Inst.* (*British*) *Mech. Eng.*, **1928**, No. 2, page 293. See also discussion, A. V. DeForest, *Trans. A. S. S. T.*, **15**, 212 (1929).

[10] V. B. Hillman, "The Cyanide Bath," *Fuels and Furnaces*, **7**, 31 (1929).

[11] H. B. Knowlton, (Case hardening) "Facts and Principles Concerning Steel and Heat-Treatment, Part 19," *Trans. A. S. S. T.*, **14**, 300 (1928).

be traced to too thin a case. If the case cannot withstand the tooth pressure the surface of the tooth will be flexed as the load is applied and released, and fatigue results. The gradation zone between the case and core is said to be the weakest toward fatigue. If this zone is near enough to the surface to receive a high stress, it will be subject to fatigue failure. Spalling is therefore suggested to be due to fatigue.

Haigh[12] suggests using an endurance specimen with a small hole drilled in it. He suggests that comparisons made in such fashion would approximate to the opinions based on practical experience, and that a hard steel that showed up well on this test might be relied upon as much as we now rely on mild steel.

Hoyt[13] has criticized the ordinary fatigue test because it does not reveal brittleness, of high phosphorus steel for example, McIntosh and Cockrell[14] have noted a slight decrease in fatigue resistance with notched specimens of high-phosphorus steel.

Atchison[15] says that fatigue tests should be supplemented by impact tests, to reveal brittleness that is not shown by the usual fatigue test.

On the other hand very little is known about the relationship between single blow notched bar impact resistance and propagation of a crack in fatigue. "Temper brittleness" certainly affects the former, but it is a question whether it affects the latter.

In the campaign to reduce fatigue failures by the use of alloys of higher endurance limits, i. e., harder steels, it is obvious that unless the rate of notch propagation is considered, the object may be defeated. In this connection the comments of Hankins and Ford[16] (see abstract, p. 117, this issue) on endurance of spring steels are of interest.

In seeking to avoid transverse fissures (which are fatigue failures) in rails, by the use of "intermediate manganese" steels, or by heat-treating the rails and thus having a higher endurance limit, it will be necessary to avoid both the presence of cracks that may act as nuclei for fissures and to see that the material is ductile enough so that the base of a notch will deform and hinder the propagation of a crack.

Cushing[17] says that in raising the tensile strength, endurance limit, etc., of rail steel, these properties must be gotten at no loss in ductility.

This factor should be given consideration in other substitutions of harder, higher yield point steels, for softer ones. For example, it is rumored that the Port of New York Authority is considering the substitution of .40–.50% carbon, 1.50–1.75% manganese steel in an important bridge, for a $3^1/_2$% nickel steel of similar carbon content. Thum[18] gives a diagram for manganese steels which indicates that the proposed composition is higher in carbon than is ordinarily considered suitable for structural steel with such a manganese content. Without full knowledge of the rate of notch propagation in the proposed steel it would seem that the substitution is a rather bold one, though with lower carbon and better notch touchness, the substitution would appear to be reasonable.

Endurance testing with drilled or notched specimens may serve for uncoated materials, but it will be difficult to standardize a notched specimen for use with coated materials.

That coated materials will have to be considered from this point of view is apparent from the recent work of McAdam[19] and Fuller.[20] McAdam finds that cadmium plating doubles the corrosion fatigue limit of uncoated steel specimens. He gives no data on the effect upon the endurance limit when corrosion is not involved.

[12] B. F. Haigh, see ref. 2.

[13] S. L. Hoyt, "Metallography, Pt. 2, Metals and Common Alloys," **1921**, 204 and 233.

[14] F. F. McIntosh and W. L. Cockrell, "Effect of Phosphorus on Resistance of Low Carbon Steel to Repeated Alternating Stresses," Carn. Inst. Tech. *Din. & Met. Inv. Bull.* **25**, 1925.

[15] L. Atchison, "Engineering Steels," **1921**, 138.

[16] G. A. Hankins and G. W. Lord, "The Mechanical and Metallurgical Properties of Spring Steels as Revealed by Laboratory Tests," *Iron & Steel Inst. (British)*, 1929—advance copy.

[17] W. C. Cushing, *Rail and Wheel, Bull. Am. Ry. Eng. Assn.*, **30**, No. 315, 2, Mar., 1929, 213.

[18] E. E. Thum, "High Strength Structural Steels," *Iron Age*, **123**, 797 (1929); "Medium Manganese Rails a Success," *Iron Age*, **123**, 940 (1929).

[19] D. J. McAdam, Jr., "Fatigue and Corrosion-Fatigue of Spring Material," *Trans. Am. Soc. Mech. Eng.*, Preprint 39a, for December, 1928, meeting.

[20] T. S. Fuller, "Some Aspects of Corrosion Fatigue," *Am. Inst' Min. & Met. Eng., Tech. Publication* **172**, 1929.

Fuller compared the same steel, bare, tinned or hot galvanized, after corrosion for a week in running tap water. True endurance tests were not made, all comparisons being on the basis of number of cycles for failure at the same stress; although the galvanized specimens were not visibly corroded, they were worse than the bare corroded specimens, while the tinned specimens were as good as or better than the uncoated and uncorroded steel.

The obvious inference is that cracks in the zinc or in the iron zinc alloy of the galvanized specimens were very readily propagated through the underlying steel.

Ordinary galvanized low carbon sheet has a steel base that is so ductile that bending too sharply will crack and flake the coating without causing the base to crack. Such material is, of course, not used in service involving repeated stress and data on fatigue resistance of galvanized sheets are lacking.

In some types of service, hard heat-treated steel is used after galvanizing. In the cables of the Mt. Hope bridge[21] galvanized, quenched and tempered steel of 190,000 lbs./sq. in. yield point was used instead of galvanized cold-drawn steel of 145,000 lbs./sq. in. tensile strength, i. e., the yield is 85% of the ultimate instead of 65%. While experience has shown that the cold drawn wire will serve, and laboratory tests indicated that the heat-treated wire was also safe under the service loads, yet after erection it was found that the wires were snapping off at the ends of the bridge where the wire had been bent in erection, or near the end where localized stress might be set up at the tangent of contact with the end fittings.

Similar failure of similar galvanized heat-treated material has been noted during the erections of the new Detroit Ambassador bridge.

It seems within the bounds of possibility that the difficulty might be due, just as in the case of chains mentioned above, not to any inherent fault of the heat-treated wire itself, but to the presence of the brittle, readily cracked, zinc and iron-zinc alloy layers. Were these layers not cracked in bending the wire, there should be no notches to be propagated, but if cracks were present, the harder material would perhaps be less well fitted to resist the advance of the crack. This is, of course, only one possibility among the many variables that will have to be considered in the study of this bridge-cable problem, but it is a possibility that deserves consideration.

Moore and Kommers[22] state that hard steels are more damaged than soft ones, as to fatigue resistance, by a few cycles of overstress, which presumably creates incipient cracks or overstrained areas, and that heat-treated alloy steels are more damaged by stress concentration than softer metals. The problem of internal stresses, introduced in quenching and not relieved by sufficient tempering, is also more serious in heat-treated steels.

A thorough study of the fatigue resistance of metals with brittle coatings, under reversed stress, as in the ordinary rotating beam machine, and also under combinations of static and alternating stresses and on both smoothly polished and scratched surfaces would be of much interest. Case hardened steel with and without sharp lines of demarcation between case and core, nitrided steel, not galvanized, sherardized and zinc-plated steel, cadmium-plated steel, steel chromium plated direct and over underlying layers of more ductile nickel or copper, tin-dipped steel, and a variety of other coated products should be studied, both on a ductile and a hard steel as base.

Lea[23] finds that nickel plating lowers the endurance limit of a 0.14% C steel something like a third and comments that the effect may be done to the formation of a crack in the coating.

The study should not be confined merely to hard coatings like a carburized case, on a softer core. It is true that, in the unscratched condition, a metal part with a harder, stronger coat will better resist fatigue, but will this be true if the part becomes scratched or marred? Would not a lead coating, for

[21] Anon., "To Dismantle Mt. Hope Bridge," *Iron Age*, **123**, 858 (1929); Anon, "Broken Wires Cause Rejection of Cables on Mt. Hope Suspension Bridge," *Eng. News-Record*, **102**, 516 (1929).

[22] H. F. Moore and J. B. Kommers, "The Fatigue of Metals," **1927**, 213 and 217.

[23] F. C. Lea, "The Penetration of Hydrogen into Metal Cathodes and Its Effect upon the Tensile Properties of Metals and Their Resistance to Repeated Stresses; with a note on the Effect of Non-Electrolytic Baths and Nickel Plating on These Properties," *Proc. Roy. Soc.*, **123A**, Mar. 6, 1929, 171.

example, render harmless blows that would form a stress-raising crack in a brittle coating?

Endurance in service is of more importance than endurance on the laboratory testing machine. As a case in point, consider the new aluminum-coated duralumin sheet. This consists of hard, heat-treated duralumin with soft pure aluminum surfaces. The endurance limit of duralumin averages perhaps 15,000 lbs./sq. in. or a little better. That of aluminum of the purity and in the softness used in the "Alclad" material will probably not run much over 5000 lbs./sq. in. though the exact figure is not quite certain.

At first sight it would appear foolish to coat the duralumin with a material whose endurance limit is so low. One would expect that cracks would start in the coating and be propagated through the duralumin since the coating is in molecular contact with it.

But as a matter of fact, the endurance limit of the "Alclad" duralumin sheet is around 10,000 lbs./sq. in., i. e., under that of sound duralumin, but above that of the coating. Uncoated duralumin is prone to intercrystalline embrittlement due to corrosion, and material so corroded is not in good shape to resist fatigue. The aluminum coat prevents that type of corrosion. It seems certain that the effective fatigue limit in actual service of duralumin has not been lowered by the use of the coating.

Metallurgists are in no position to-day to predict the behavior of duplex metals in service where repeated stresses, or even high static stresses, must be withstood. Before such predictions can be made, much more information must be obtained about the rate of propagation of a crack in a metallic coating through a metallic core.—H. W. GILLETT

Corrosion of Iron; Correlation of A. S. T. M. Test Data

The American Society for Testing Materials has carried out very comprehensive atmospheric exposure and submerged corrosion tests over a long period of years. The series of tests on uncoated sheet metal is now far enough advanced to make it possible to study the data with some degree of finality.

Two papers[1] at the June meeting of the Society survey the data by means of plotting on probability paper. Passano and Hayes deal with the general method, using A. S. T. M. data as illustrative. They conclude that the application of the probability method shows "that reckoning the lives of ferrous materials from a small number of samples is likely to yield an accidental result, and that variation in the service can only be gaged from studies under the conditions in which the material serves."

Kendall and Taylerson not only attack the problem through the medium of plotting on probability paper, but by applying mechanical tabulation of punched cards (such as is used in working up the Census), attempt to find the effect of different variables.

In the total immersion tests in Severn river water (brackish), Washington City water, and Calumet mine water, the results indicate, they say, "that the variation in common elements, either singly or in combination, within the range of composition and under the conditions of these tests, has no material influence on corrosion resistance and is entirely secondary to external conditions."

The study of the atmospheric exposure tests, on the other hand, confirms the previous conclusion of A. S. T. M. Committee No. 5, that copper-bearing metal shows superiority in rust-resisting properties, and also indicates that manganese and sulphur, within the composition range studied, have little effect either way, but that, in the presence of 0.15 to 0.30% copper, increase in phosphorus, at least up to 0.10 or 0.11%, raises the life considerably. The curves show that with 0.03% P the average life of the 22 gage copper bearing sheets in the Pittsburgh test was about 1500 days, and with 0.10% P around 2200 days.

[1] V. N. Kendall and E. S. Taylerson (National Tube Company and American Sheet & Tin Plate Company), "A Critical Study of the A. S. T. M. Corrosion Data on Uncoated Commercial Iron and Steel Sheets." (Preprint No. 37, 16 pp.); R. F. Passano and A. Hayes (American Rolling Mill Company), "A Method of Treating Data on the Lives of Ferrous Materials" (Preprint No. 38, 12 pp.). Both preprints for *Proc. Am. Soc. Test. Matls.*, **29** (2), 1929.

This reminds one of the recent patent to F. R. Palmer of the Carpenter Steel Company in which it is claimed that steel of high phosphorus content is unusually resistant to oxidation at high temperatures. The question of the type of oxide formed when some oxide of phosphorus is simultaneously formed, is an interesting one. Perhaps we shall revert to conditions such as existed in the days when chemistry was first being applied to steel, and a customer asked a steel salesman who was quite innocent of chemical knowledge, "What about sulphur and phosphorus in your steel?" to which the salesman replied, "We'll give you twice as much sulphur and phosphorus as any of our competitors."—H. W. GILLETT

Recent Work on Fatigue and Corrosion—Fatigue of Steel

Three important papers dealing with fatigue and corrosion-fatigue of steel were presented at the meeting of the American Society for Testing Materials.[1]

Peterson, actuated by a desire to test scale models of rotor shafts in which the machining of fine details to scale required the use of specimens much larger than those normally used in fatigue testing, has designed cantilever endurance machines for specimens whose critical section is $2^1/_4$" or 1" diameter instead of 0.3" or 0.5". The weights required are so heavy that they are applied through a lever system instead of direct. By attaching a fan to the shaft an air current may be directed onto the ball or roller bearings used and keep them from excessive heating under the heavy loads.

Use of a 1" diam. specimen in testing of double-V butt welds gave the same endurance limit as when 0.3" diam. specimens were used, but the S-N curve for the larger specimen was remarkably free from scatter. Publication of results on a series of tests of welds is promised for the future. This paper relates to the testing equipment.

McAdam has continued his study of how long corrosion must go on under reversed stresses of different magnitudes applied at different rates in order that, under subsequent endurance testing without corrosion, the endurance limit will drop a definite amount.

For example, a heat-treated 0.46 carbon steel of 130,000 lbs./sq. in. tensile strength has an endurance limit of 59,000 lbs./sq. in. According to McAdam's curves, in order to corrode it enough in fresh (carbonate) water so that the endurance limit is halved, one may corrode it 2000 days at 15,000 lbs./sq. in. reversed stress at 1 revolution per day; or $1^1/_2$ days at the same reversed stress at 10,000 r. p. m.

A heat-treated duralumin of fairly normal tensile properties and an endurance limit given as 15,600 lbs./sq. in. (the number of cycles used in determining the endurance limit is not stated), corroded at a cyclic stress of 6000 lbs./sq. in., has the endurance limit dropped as follows:

to 13,000 lbs./sq. in. after about 3 days at 1450 r. p. m.
to 12,000 lbs./sq. in. after about $4^1/_2$ days at 1450 r. p. m.
to 11,000 lbs./sq. in. after about 7 days at 1450 r. p. m.
to 10,000 lbs./sq. in. after about 10 days at 1450 r. p. m.

In order to drop the endurance limit of a stainless iron (0.11% C, 12.7% Cr, quenched and drawn to 100,000 lbs./sq. in. tensile), from 50,000 down to 45,000 lbs./sq. in., it must be corroded one day at 40,000 lbs./sq. in. cyclic stress at 1450 r. p. m. or 200 days at $1^1/_2$ r. p. m.

For ordinary steels and duralumin McAdam concludes that any cyclic stress, no matter how small, accelerates corrosion. It has not yet been determined whether or not this is true for stainless steel and monel metal.

[1] R. E. Peterson (Westinghouse Electric & Manufacturing Company), "Fatigue Tests of Large Specimens" (Preprint No. 45, 8 pp.); D. J. McAdam (U. S. Naval Eng. Expt. Sta.), "Corrosion of Metals under Cyclic Stress" (Preprint No. 40, 54 pp., 23 figs.); F. N. Speller, I. B. McCorkle and P. F. Mumma (National Tube Company), "The Influence of Corrosion Accelerators and Inhibitors on Fatigue of Ferrous Metals" (Preprint No. 41, 12 pp.). All from *Proc. Am. Soc. Test. Matls.*, **29** (2), 1929.

The effects of the many variables included in McAdam's work are shown by families of curves, on two and three dimensional diagrams. Some of the data in the present paper were obtained from rotating cantilever tests running at 10,000 r. p. m. The specimens gave trouble from vibration and it was necessary to lighten the attachments to the end of the specimen and apply the load through a stretched spring rather than by weights. No study is recorded to show what the error in the calculated stress may be at this high speed.

Speller and collaborators carried farther their work on sodium chromate or dichromate to overcome the corrosion of chloride waters on a 0.42% carbon steel. General corrosion under repeated stress at 34,000 lbs./sq. in., or 2000 lbs. below the endurance limit in air, was stopped in water such as Pittsburgh tap water, low in chlorides, by 175 parts per million of dichromate. When 2000 p. p. m. of NaCl were present (corresponding to oil well mud fluids), it took 8000 p. p. m. of chromate to stop corrosion under the condition of repeated stress, and with 3000 p. p. m. of NaCl (corresponding to sea water), it took 8000 p. p. m. of chromate. Dichromate did not prevent corrosion under stress as well as chromate.

But if any *local* corrosion is present, as when a rubber washer was fitted around the middle of the test specimen, no concentration of chromate or dichromate tried was effective. While the carbon steel drops from 36,000 to 26,000 lbs./sq. in. endurance limit through general corrosion fatigue in Pittsburgh tap water and to 20,000 through localized corrosion fatigue, stainless steel drops from 45,000 to 38,000 and 36,000 under the same conditions.

Speller emphasizes that corrosion fatigue is controlled by the factors controlling ordinary corrosion. When corrosion goes on so that pits are formed, then the specimen acts as any endurance specimen so notched or pitted would act. The effect of repeated stress in accelerating corrosion is due to the breaking of the protective surface film. A thin, flexible film is required to stand up against breakage. The films automatically formed on stainless steel are more stable than those formed on carbon steel in chromate or dichromate solutions.—H. W. GILLETT

Table 2

BRINELL HARDNESS NUMBER AT VARYING TEMPERING TEMPERATURES—SPECIMENS 3" x 3/8" CROSS SECTION

	Quench, ° C.	Medium	—TEMPERING TEMPERATURES, DEGREE, C.— As Quenched	250	300	350	400	450	500	550	600
S2—low Cr	800	Oil	630	620	590	580	510	450	430	415	365
S4—high Cr	820	Oil	560	550	500	480	465	435	395	380	335
S6—Ni-Cr	820[a]	Oil	537	515	505	480	455	410	365	358	335
S1—0.60% C	800	Water at 50° C.[b]	610[d]	590	550	490	475	430	380	350	300
S3—0.46% C	810[c]	Water at 25° C.	550[d]	540	540	490	450	390	340	310	280
0.82% C.	950	Oil	590	545	545	490	444	318	369	351	315
Si-Mn	950	Oil	600	566	550	550	540	490	428	372	345
Si-Mn	870	Water	650	590	575	545	540	500	424	387	336
Cr-V	850	Oil	640	620	578	540	512	477	466	444	400

[a] Fifteen min. at temperature.

[b] Specimens quenched from 950° to 800° into water at 18° C. cracked. No obvious cracks were found in 3" and 6" lengths, but were present in 18" lengths when quenched into water at 50° C.

[c] Twenty min. at temperature.

[d] Uniformity of hardness not good even in small specimens.

Table 3

COMPARISON OF PROPERTIES OF STEELS QUENCHED AS SHOWN IN TABLE 2 AND TEMPERED TO STATED BRINELL NUMBERS

		470 Brinell			410 Brinell			350 Brinell		
Steel	Quench	Static Prop. Limit 1000 Lbs./-sq. in.	End. Limit 1000 Lbs./-sq. in.	Izod[a] ft. lb.	Prop. Limit	End. Limit	Izod	Prop. Limit	End. Limit	Izod
0.46% C	Water	...	...	...	97	79	3	88	79	17
0.60% C	Water (50° C.)	...	101	8	...	86	12	...	81	27
0.60% C	Oil	150	106	2	130	90	13	117	84	19
0.80% C	Oil	...	...	..	...	...	..	81	86	12
Low Cr	Oil	167	103	5	150	92	14	106	84	23
High Cr	Oil	154	110	12	136	90	17	106	84	50
CrV	Oil	154	97	13	139	96	23	110	90	45
SiMn	Oil	150	106	9	134	101	12	112	86	17
SiMn	Water	183	110	11	154	101	14	119	86	19
NiCr	Oil	132	110	5	134	97	15	117	90	30

[a] 9 mm. x 9 mm. specimens 45° notch, 1 mm. deep, 1/4 mm. root radius.

The Mechanical and Metallurgical Properties of Spring Steels as Revealed by Laboratory Tests

Hankins, G. A., and Ford, G. W., (Natl. Phys. Lab.)
Advance copy—British Iron and Steel Institute, 1929 Spring Meeting

Continuation of work for the Springs Research Committee of the British Department of Scientific and Industrial Research, on which earlier phases dealing with 0.60 and 0.80% carbon plain carbon steels oil quenched a silico-manganese and a chromium-vanadium steel have previously been published.[1] This paper gives data on several additional steels: Both sets of data are summarized together.

Table 1

COMPOSITION OF STEELS

No.	C	Si	S	P	Mn	Ni	Cr	V	
S2	0.60	0.26	0.036	0.036	0.62	..	0.56	..	Low chromium
S4	0.45	0.12	0.010	0.014	0.69	..	1.14	..	High chromium
S7	0.36	0.29	0.020	0.023	0.50	3.42	0.60	..	Nickel chromium
S1	0.60	0.21	0.007	0.012	0.77	0.08	0.09	..	Water quenched carbon
S3	0.46	0.09	0.037	0.026	0.51	0.03	..	..	Water quenched carbon
..	0.82	0.25	0.019	0.026	0.41	..	tr.	..	Oil quenched carbon
..	0.54	1.95	0.021	0.021	0.94	..	tr.	..	Silico-manganese
..	0.55	0.29	tr.	0.006	0.68	0.10	1.16	0.27	Chromium-vanadium

[1] G. A. Hankins, D. Hanson and G. W. Ford, "The Mechanical Properties of Four Heat-Treated Spring Steels," *Jour. Iron and Steel Inst.*, **114**, No. II, 265 (1926).

The endurance limits were obtained on carefully polished rotating cantilever specimens, run to ten million cycles without failure. It is stated that results would be sufficiently accurate on steels of this type, if the tests were run only to two million cycles.

The stresses at which failures occur in actual springs are far below the inherent endurance limits of the steels. For example, complete springs of 0.60% C (oil quenched), Cr-V and Si-Mn had a safe range of only from no load to 44,000 lbs./sq. in., although the endurance limits were about 88,000 lbs./sq. in. or an endurance range of 176,000 lbs./sq. in. on polished test pieces.

The Si-Mn steel which gave 101,000 lbs./sq. in. endurance limit on specimens ground and polished after heat-treatment, gave only 60,000 lbs./sq. in. when the same heat-treatment was applied to specimens ground and polished *before* heat-treatment and not repolished. The Cr-V steel gave 93,500 lbs./sq. in. on specimens similarly polished after heat-treatment while those polished *before* gave but 70,500 lbs./sq. in.

It is concluded that surface irregularities, pits, lines and scratches on the surface of a spring vastly affect the engineering endurance limit of a spring. The presence of a decarburized surface layer, due to heat treatment is conducive to the formation of surface cracks at low stresses, the stress concentration at the apex of the crack then causing it to extend into the middle of the spring and cause failure.

The susceptibility to penetration of a crack may not be exactly measured by the Izod value, but "other things being equal, the steel possessing the highest Izod value appears to be the best one to select for a spring." Decarburization should be reduced to a minimum and complete surface grinding and polishing of spring plates after heat treatment may be worthy of consideration in special cases.—H. W. GILLETT

Abstracts of Current Metallurgical Literature

In this section, there will each month appear brief abstracts of articles in the metallurgical field appearing in various publications. These abstracts are not critical, but merely review developments as they are recorded. Every effort will be made to report on all articles as soon as possible. In the very near future the abstracts will be arranged according to subject.

Der Bruch Gekerbter Zugproben. W. KUNTZ. *Mitteilungen der deutschen Materialprüfungsanstalten*, Heft 3–4, 1929, pages 36–37.

Original in Berichte des Werkstoffausschusses des Vereins deutscher Eisenhüttenleute, No. 129, 1928. The knowledge of the usual physical constants of materials is not sufficient to numerically determine the strength of bodies which have an essentially different shape from that of the samples from which the constants were derived. An attempt was therefore made to find a relation, eventually a mathematical expression for a change in strength with a change in shape, and in this way to lay down a so-called material constant independent of the shape. A diagram shows the results for tensile strength tests made with rods, the shape of which were changed by notches of different depth and different angles, by extrapolation a value for the unnotched body was determined. The quotient "tensile strength/sliding strength" was found to be equal to 1 for very brittle materials, about 2 for unalloyed, annealed materials. Elongation increased this constant to 2.7 maximum. Further diagrams are given for different steels. It is pointed out that the refining of a material should be in the direction of the most favorable tensile strength. HA.

Wärmeausdehungsmessungen. H. SIEGLERSCHMIDT. *Mitteilungen der deutschen Materialprüfungsanstalten*, Heft 3–4, 1929, pages 41–42.

By means of an apparatus of quartz-glass (described in the Zeitschrift für Instrumentenkunde, Vol. 45 (1925), pages 374–378) the thermal expansion coefficients for several materials, cast iron, steel, nickel alloys, wires of aluminum alloys, bronze and copper, and of zinc have been determined for temperatures between 20° and 500° C. The results are given in tables. HA.

Zur Durchführung der Kerbschlagprobe mit Kesselblechen. R. BAUMANN. *Mitteilungen der deutschen Materialprüfungsanstalten*, Heft 3–4, 1929, pages 42–43.

Original in the Zeitschrift des Bayrischen Revisionsvereins, No. 16/17, 1927, page 1. The author advocates retaining the present method of boiler plate testing, which requires the minimum notch toughness at normal temperature, against the recent attempts to establish the temperature as characteristic for the steep gradient of notch toughness, because the first method permits recognizing more clearly the quality of boiler plates with respect to their annealing treatment. The second method offers a better indication as regards manufacturing and working methods. HA.

Untersuchungen an Kristallen von β-Messing. FREIHERR VON GÖLER & G. SACHS. *Mitteilungen der deutschen Materialprüfungsanstalten*, Heft 3–4, 1929, pages 47–48.

Original in Naturwissenschaften, Vol. 16 (1928), pages 412–416. The series of alloys of copper-zinc shows intermediary solid solutions between 51 and 55% Cu, which have found considerable interest as a basis of the much used brasses, high in zinc. These solid solutions are similar to α-iron especially in that they also possess a kind of "transformation." The tests are described in detail. HA.

Die Löslichkeit von Kupfer in Silber. M. HANSEN. *Zeitschrift für Metallkunde*, June, 1929, pages 181–184.

Report of the Kaiser Wilhelm Institut für Metallforschung. The solubility of copper in silver was previously studied by thermic and microscopic methods which show that the solubility increases with increasing temperature. The present investigation was to exactly determine the entire solubility curve. The curve of the end of the freezing and the saturation limit of solid solutions of rich silver contents were determined by microscopic analysis of annealed and quenched alloys. The solubility of copper in silver increases from about 1.7% Cu at 250° to about 9% Cu at the eutectic temperature (779° C.) and has at the intermediate temperatures of 300, 400, 500, 600, and 700° C. the values 1.7, 2.2, 3.2, 5.0 and 7.2%, respectively. At the same time also the microscopic structure is examined and illustrated in micrographs. Numerous bibliographical notes are given. HA.

Ueber die Zähigkeit Fester Körper. S. ERK. *Zeitschrift für Metallkunde*, June, 1929, pages 185–189.

This paper considers the plasticity of solid materials and the static and dynamic methods of measuring toughness. The conclusions drawn are: All materials, including the so-called "solid" have the capacity of flowing under the influence of a force of sufficiently long duration, i. e., they behave like liquids of great viscosity. The methods so far employed to measure the viscosity of solid materials can be divided into two groups, the static and dynamic. In the dynamic methods, the viscosity is calculated from the decrement of oscillations; however, this method does not give correct values. With the static methods, the permanent deformation of the sample is observed, which supplies quantitatively correct values, which however depend on the pre-treatment for crystalline materials (metals). The experimental difficulties are considerable, therefore, the accuracy of the results is low. The failure of the dynamic methods is explained through the kinetic gas theory. Viscosity measurements of metals can give indications in reference to the influence of thermal and mechanical treatments. HA.

Der Einfluss von Dritten Metallen auf die Konstitution der Messinglegierungen. 1. Der Einfluss von Blei. O. BAUER & M. HANSEN. *Zeitschrift für Metallkunde*, June, 1929, pages 190–196.

This extremely comprehensive investigation into the behavior of the ternary system Pb–Zn–Cu was carried out in the range of 100 to 52% Cu and 0 to 2.5% Pb. Thermal and microscopic tests were made and numerous diagrams and micrographs of the structure of these alloys are given. In general the freezing of these alloys is analogous to that of the lead-copper alloys. Alloys with much copper disintegrate between 954 and 890° C. The paper is supplemented by 48 bibliographical references. HA.

Herrichtung von Aluminumlegierungen für die Mikroskopische Untersuchung. HEINZ CHOULANT. *Zeitschrift für Metallkunde*, June, 1929, pages 197–199.

The etching reagents for aluminum alloys and the methods for the preparation of sections are discussed. As a new etching reagent a 5% alcoholic solution of ferric-nitrate is proposed. The usefulness of this method is proved by a few cast alloys and by quenched and annealed duraluminum. HA.

Die Widerstandsfähigkeit von Chromnickel-Thermoelementen Gegenüber Metallschmelzen. R. HASE. *Zeitschrift für Metallkunde*, June, 1929, pages 200–203.

This article describes in detail extensive tests made to determine the resistivity of chromium-nickel thermocouples, when used in direct contact with molten metals. From the results, it is concluded that chrome-nickel tubes drilled from the solid body are the most resistant against corrosion by the molten material. HA.

Untersuchungen über die Korrosion von Metallen der Kraftfahrzeuge Durch Brennstoffe und Brennstoffmischungen. K. R. DIETRICH. *Korrosion und Metallschutz*, May, 1929, pages 110–114.

From observations extending over a period of one year and a half made with the purpose of discovering the influence of different fuels and their combustion products on materials used in the automobile industry, the following general conclusions were drawn: iron was corroded by all fuels used, forming iron-oxide or iron sulphide. Zinc was attacked by fuels containing sulphur, copper also, but to a lesser degree. Aluminum, hard or soft was not attacked. Lautal was strongly attacked. Iron plated with nickel was corrosion proof, as was also tinned iron. Lead coated was only corrosion proof against absolute alcohol, other fuels attacked the lead coating. Galvanized iron was corroded strongly only by sulphur content fuels. Brass and bronze castings were corrosion proof. HA.

Influence de l'Azote Sur Les Aciers Speciaux et Expériences Sur La Nitruration. M. SHUN-ICHI SATOH. *Revue de Métallurgie*, May, 1929, pages 248–258.

Nitrogen has an unfavorable influence on iron and steel, although on the other hand, it accelerates the cementation process. It produces an extremely hard surface on special steels. The author compiles the results of the experiments made in this direction and experimented with steels containing chromium, aluminum, titanium, manganese, zirconium, molybdenum, tungsten and uranium in a current of ammonia at 580 to 560° C.; the Brinell Hardness was measured and the relation between the different elements and their ability to harden the steel. It was found that aluminum

and titanium gave the hardest surfaces. Many micrographs and 73 bibliographic references supplement the paper. HA.

La Corrosion des Métaux et Alliages Légers et Ultra Légers. M. CAZAUD & A. PETIT. *Revue de Métallurgie*, May, 1929, pages 259–286.

The second part of this investigation deals with the resistivity against corrosion of magnesium and ultra light alloys. The methods of testing and analyses of the samples are given; test results are shown in curves and diagrams. Their behavior towards corroding influences can be judged by microscopic examination after only a few hours' immersion in sea water. It was shown that this rapid method is in every way as accurate as other methods requiring longer times. In general, it can be said that, of all the elements used for alloying with aluminum, silicon and manganese have a favorable influence, while magnesium is unfavorable. Duraluminum is attacked more when annealed than in the treated state. HA.

Ueber Die Flüchtigkeit der Oxyde von Blei, Cadmium, Zink und Zinn. DR.-ING. FEISER. *Metall. und Erz*, June 1, 1929, pages 269–284.

The working and preparation of ores and intermediary products by means of sublimation methods has lately gained considerable importance in metallurgical practice. To this end the knowledge of exact information on the volatility of the materials in question is necessary. By determination of the loss in weight the vapor pressures of PbO, CdO, ZnO and SnO_2 have been found for temperatures up to 1500° C. It was found that PbO is volatile from 750° C., CdO from 900° C., ZnO from 1300° C. and SnO_2 from 1350° C. The boiling point of PbO was determined as 1472° C., the sublimation point of CdO as 1380–1390° C. The slightly volatile oxides of SiO_2, Fe_2O_3 and SnO_2 reduce the volatility of the PbO. An attempt was made to separate PbO in converter dust from the other oxides. This was successful, PbO could be almost completely separated, but if 2–5% SiO_2 was present in the dust such a complete separation was not possible. HA.

Wolfram Als Chemisch-Technischer Werkstoff. H. ALTERTUM. *Metall. und Erz*, June 1, 1929, pages 288–289.

This article gives information on the more important ores and deposits. The contents vary between 0.5 and 2% W. Most of the material is used as ferro-tungsten with 80–85% W. Preparation by flotation and magnetic methods is discussed. Different methods are described for the preparation of tungstenates and metallic tungsten. An electrolytic process is also possible for the production of neutral basic tungstenates at temperatures of 700–1000° C. HA

Korrosionsschutz von Vergutbaren Alluminumlegierungen in Flugzeugbau. PAUL BRENNER. *Luftfahrtforschung*, May 29, 1929, pages 137–141.

An investigation of protection methods against the corrosion of metals, in particular light-metals, used in aeroplanes and airships, had the following results: Refinable aluminum alloys can be coated with paints, oxide coatings, electroplated or welded coats. The most effective is the welded metallic coat because it gives to the refinable aluminum alloy an extraordinary increase of resistance to corrosion. This method combined with another surface protection nowadays seems the best protection. Tests are given in detail and a list of references are included. HA.

Wire Products in Aircraft Industry. JOHN F. HARDECKER. *Wire and Wire Products*, July, 1929, pages 225–227, 246.

This article presents information on rivets, nails, springs, cotter pins and miscellaneous wire items used in abundance in the aircraft industry.

The Magnetic Analysis of Wire. JOHN S. HOFFHINE. *Wire and Wire Products*, July, 1929, pages 228–229, 245.

A new simplified method is described.

Nickel Cast Iron Engine Cylinders. E. J. BOTHWELL. *Aero Digest*, July, 1929, pages 104 and 105.

A brief history of the S. Cheney & Son Company is given. Then the production of nickel cast iron cylinders is discussed.

A Study on the Constitution of High Manganese Steels. V. N. KRIVOBOK. *Transactions American Society for Steel Treating*, June, 1929, pages 893–956.

Includes discussion. 30 photomicrographs. Paper presented at tenth annual meeting of the Society held in Philadelphia, October 8 to 12, 1928. These experiments deal with the constituents of austenitic manganese steel under different conditions of treatment. It is shown that cold working of this steel to certain various temperatures (500° to 1000°) brings about the decomposition of the original austenite. Temperatures up to 1200° indicate the decomposition to be a formation of troostite. With a temperature treatment approaching 1400° troostite and pearlite have disappeared and iron-manganese-carbides appear. It is concluded that the internal strain occurring along crystallographic planes in the austenitic constituent is a determining factor in the formation of the new structure. This is demonstrated by the comparison of strained and unstrained specimens identically treated. Above 1400° cementite is in the separating phase. A theory of "martenization" is discussed in detail advancing the idea that the term martensite as applied to special steels pertains largely if not altogether to form and that it is not justifiable to attribute to it certain properties such as composition and hardness. E. S. C

Torsional Modulus of Carbon Steel, Phosphor Bronze, Brass and Monel Metal. W. P. WOOD. *Transactions of the American Society for Steel Treating*, June, 1929, pages 971–985.

Includes discussion. Deflection method was used for determination of torsional modulus. Measurements were made in three types of steel, phosphor bronze, brass and monel metal carefully selected specimens. Av. value of torsional modulus for steel, 11,454,000; for phosphor bronze, 6,330,000; for brass, 4,950,000; for monel metal, 8,003,000. E. S. C.

Graphitization in the Presence of Nickel. H. A. SCHWARTZ. *Transactions American Society for Steel Treating*, June, 1929, pages 956–970.

Includes discussion. Experiments demonstrate that in the presence of even rather low nickel concentrations, silicon becomes inactive as an accelerator of graphitization. The graphite formed by a given heat treatment is very nearly proportional to the nickel content. The graphite formed at a given temperature is proportional to about the $^2/_3$ or $^3/_4$ power of time up to the point where as much as 86 per cent of the possible graphite formation has taken place. The thermal coefficient of graphitizing rate accelerated by silicon and nickel is shown to be similar. No conclusions as to the mechanism of graphitization in the presence of nickel are drawn but data are presented to show the cancellation of the effect of silicon by nickel. If these reasons are true, they constitute further confirmation as to the difference in kind of stable and metastable solutions of carbon in iron. E. S. C.

Changes in Hardness and Structure in Annealed Cold-Rolled Steel. *Iron & Coal Trades Review*, June 28, 1929, pages 970.

A summary of an article by Ragnar Jonson in a recent issue of "Jernkontorets Annaler." Steels (C 1.15, 0.90% and 0.60%) after subjection to different degrees of reduction by cold-rolling were annealed and tested as to hardness and structure. Results: (1) After cold-rolling, re-crystallization takes place within a certain range of temperature. Assuming the temperature of incipient re-crystallization to be the temperature at which the hardness of the cold-rolled material, after showing a maximum hardness at 300–500° C., recovers the value which it had in the cold rolled but unannealed condition, and assuming the temperature of completed re-crystallization that temperature at which the hardness has attained the value it had before the cold-rolling, the investigation goes to prove: (a) that these temperatures are higher in proportion to the carbon content, and (b) that they are dependent on the degree of reduction by rolling. (2) As the influence of cold-rolling in regard to hardness is certainly neutralized at 650° C. in the case of the lowest degree of reduction by cold-rolling in question (32.5%), the most suitable annealing temperature will probably be found between that temperature and Ac. The nearer to Ac, the better, as greater ductility is the result. (3) By determining the critical temperature and examining the hardness and microstructure it is found that the risk of overheating in soft annealing is greatest with 0.9% C, not as great with 0.6% C, and least with 1.15% C. (4) An extended annealing period of 1–5 hours has little effect on hardness and structure. W. H. B.

The Manufacture of Iron and Steel Tubes. JAMES MITCHELL. *Iron & Coal Trades Review*, June 21, 1929, pages 933–5.

An attempt to describe comprehensively the methods now in use in the manufacture of iron and steel tubes and to indicate some of the lines along which development may be expected. The processes of making tubes by butt-welding, lap-welding, hand-welding, electrical-welding and of weldless tubes are included in the discussion. Also the production of tubes from the hollow blooms. W. H. B.

Production of Sound Ingots. *Iron & Coal Trades Review*, June 14, 1929. Further discussion of the paper by Charles Parsons and H. M. Duncan (cf. *Ibid.*, May 3, 1929, pages 654–5, and May 17, 1929, pages 758–60), and a reply by Duncan. W. H. B.

Casting Steel in Water-Cooled Copper Moulds. *Iron & Coal Trades Review*, June 14, 1929, pages 898–9.

An abstract of an article in "Stahl und Eisen" by W. Oertel. Experimental steel castings were made in moulds consisting of a conical copper pipe 8″ in diameter, 20 m.m. (.78″) gauge and 40″ long. For a length of $2^3/_4$″ the copper pipe was encased in a cast iron jacket, forming tight joints with the pipe at both ends by screwed unions. The bottom of the mould was formed of a removable iron plate. Cooling water is passed through a 2″ pipe

at the bottom of the mould, which may be tilted. Tables show: a comparison of steels cast in cooled copper moulds and in ordinary chill moulds; the chemical composition of melts; results of a test run; range of hardness of cast magnet steels; and magnetic properties of cast magnet steels. The experiments are only preliminary, but water-cooled copper moulds indicate a saving in costs due to the need of fewer moulds, and they appear not to be subject to any appreciable wear. The castings have a smooth clean surface, rarely requiring turning down. W. H. B.

Plating Shop Layout and Equipment. *Brass World*, June, 1929, pages 138–40. A discussion of J. W. Peering's paper entitled, "Electroplating Plant," and read before the March Meeting of the Electroplaters' and Depositors' Technical Society, London. Types of vats, heating, thermostats and a good layout are points discussed. W. H. B.

New Type Annealing Furnace. *Brass World*, June, 1929, page 148.

The Brandt furnace recently put out by Weisberg and Greewald, New York City, anneals, solders, or heat treats metals, such as gold, nickel silver and sterling silver without oxidizing them. Savings in costs are claimed for this furnace in soldering. W. H. B.

The Microstructure of Rapidly-Cooled Steel. J. M. Robertson. *Iron & Coal Trades Review*, June 7, 1929, pages 864–6. Cf. *Ibid.*, May 24, 1929, pages 790–2; May 31, 1929, pages 829–30.

This, the concluding section, deals with the following points: Relation of the structures to the theory of heat treatment; Ar′ suppressed by cooling in molten tin below 420° C.; Structures formed at different temperatures; Nature of the Ar′ and the Ar″ transformations; and Crystallographic form of the structures formed at the Ar″points. Small steel specimens were cooled in molten tin at various temperatures between 600° and 220° C., permitting observation of the sequence of structures obtained when austenite is caused to decompose at progressively lower temperatures. The ultimate composition of the product of austenite appears to vary gradually as the temperature at which the transition takes place is lowered. The crystallographic form of the decomposition is initiated by the allotropic change or by the formation of cementite. The Ar′ change is initiated by cementite, while the Ar″ transformation is initiated by the allotropic change and the structures formed at this change point are related to the crystallographic planes of the austenite. The relations between Ar′ and Ar″ points are determined by the fact that the allotropic change and the formation of cementite are differently affected by variation in the rate of cooling. There are two series of structures produced by increasing the rate of cooling. Within each the variation in structure is gradual. The structures formed by cooling at different rates cannot be obtained by tempering other structures. As regards crystallographic form or structure, no relation is evident between cooling at different rates and tempering at different temperatures. The same ultimate constitution may be produced in two ways: when the α-solid solution produced by very rapid cooling is reheated, carbon gradually separates from solution and forms cementite. By reheating to different temperatures all variations in constitution between solid solution and ferrite-cementite aggregate may be obtained. The results described in the paper are part of a research on intermediate rates of cooling and their relation to wire-drawing for the Wire Ropes Committee of the Safety in Mines Research Board. W. H. B.

Zur Bestimmung der Gase in Metallen, besonders des Sauerstoffs in Eisen und Stahl, nach dem Heissextraktionsverfahren. Hans Diergarten. *Archiv. für Eisenhüttenwesen*, June, 1929, pages 813–828.

This paper principally deals with the further development and testing of apparatus for oxygen determination by the hot extraction method. Report No. 63 of the Chemical Committee of the Verein deutscher Eisenhüttenleute.

Bestimmung der Oxydischen Einschlüsse in Eisen und Stahl auf Rückstandsanalytischem Wege durch Chloraufschluss. Roland Wasmuht & Paul Oberhoffer. *Archiv. für Eisenhüttenwesen*, June, 1929, pages 829–842.

Report No. 64 of the Chemical Committee of the Verein deutscher Eisenhüttenleute. To determine the oxide constituents of the iron and steel, the metallic constituents of the sample are taken up by a chlorine stream and drawn off, while the non-metallic oxide constituents remain behind unattacked.

Die Bedeutung der Ersten Glühung für Qualitätsfeinbleche, Ihr Einfluss auf die Erichsen-Tiefung und das Gefüge. E. Marke. *Archiv für Eisenhüttenwesen*, June, 1929, pages 851–858.

Report No. 150 of the Materials Committee of the Verein deutscher Eisenhüttenleute. This article points out that all quality sheets, which are only subjected to a single anneal and which should give a good Erichsen test and a structure free from rolling structure, should at least be heated to 750° C.

Der Einfluss der Stichabnahme und der Glühtemperatur auf die Mechanischen Eigenschaften und das Gefüge von Kaltgewalzien Feinblechen. Anton Pomp & Ludwig Walther. *Archiv für Eisenhüttenwesen*, June, 1929, pages 859–865, also *Stahl und Eisen*, June 27, 1929, page 941.

Report No. 151 of the Materials Committee of the Verein deutscher Eisenhüttenleute. Sheets with different reductions and different numbers of passes were rolled cold and then annealed at 650, 750 and 920° C. for 3 hours. The physical and microscopic investigations showed that the anneal at 920° C. gave the best physical properties and a uniform structure, regardless of the degree of deformation. The anneal at 750° C. approximates the values of the 920° C. anneal, if to avoid damaging the material in the critical range a cold working of over 20% is used. A three hour anneal at 650° C. is not sufficient to get rid of the hardness due to cold working. Further the sheets rolled cold with from 1 to 36 passes and about 30% reduction were annealed at 750° C. for three hours. The investigation showed that the number of passes had no influence on the cupping of the annealed sheets.

Ueber das Spezifische Volumen von Weissem Roheisen. Leo Zimmermann & Hans Esser. *Archiv für Eisenhüttenwesen*, June, 1929, pages 867–870, also *Stahl und Eisen*, June 20, 1929, pages 912–913.

This article describes a dilatometric method for the determination of specific volume of metals. The experiments included various white cast irons of similar chemical composition up to temperatures of 1300° C. The numerical results showed only slight deviations. The values found for increase in volume in melting with white cast iron having 3.5 to 3.92% C, 0.13 to 0.67% Si and 0.06 to 0.1% Mn were between 1.33 and 1.41%.

Der Einfluss der Wärmebehandlung auf die Güte von Wolframstahl. F. Polzguver and W. Zieler. *Stahl und Eisen*, April 18, 1929, pages 521–527.

Report No. 144 of the Werkstoffausschuss of the Verein deutscher Eisenhüttenleute. Includes discussion. This report points out that for the most tungsten-steels there is a definite critical temperature range, in which WC separates out if the heating at this temperature is long enough. This causes a decrease in the physical properties. Only with very low carbon tungsten steels, which though due to their low hardness have no practical value, is there no separation of the WC. Further the formation of the carbide has very little influence, if the steel has a high carbon content with a high tungsten content, so that the necessary amount of carbon remains in solution for the occurrence of a good hardening effect. The critical temperature range varies with the chemical composition and must be determined for each steel group by systematic investigations. Holding a long time at the critical temperature as well as a subsequent slow cooling absolutely must be avoided in the working of the steels. A slight addition of chromium, as is often used in practice, is recommended, as the steels are then less sensitive to improper heat treatment.

Soft X-Rays from a Single Nickel Crystal. S. R. Rao. *Nature*, March 9, 1929, pages 344–345.

The inflections in the curve obtained by plotting applied potential against the energy of the soft X-rays excited, as measured by the photo-electric method, are recorded for a single crystal of nickel.

Line Absorption Spectra in Solids at Low Temperatures in the Visible and Ultra-violet Regions of the Spectrum. S. Freed and F. Spedding. *Nature*, April 6, 1929, pages 525–526.

A short account of the line absorption spectra (comparable with line emission spectra) of gadolinium, samarium and erbium.

Uber Ternare Diagramme auf der Grundlage Eisen-Kohlenstoff. E. Scheil. *Mitteilungen des Forschungs-Institut Vereingte Stahlwerke A. G.*, Dortmund. Vol. I, 1928, pages 1–21.

Discussion of the theories of equilibrium diagrams with many sections of solid diagrams for Fe_3C and Fe with Si, P, and some with Mn, Ni and Cr.

Arc Welding of Steel Buildings and Bridges. F. P. McKibben. *Journal American Institute of Electrical Engineers*, May, 1929, pages 393–396.

The paper treats of the important matters of the revision of building codes, the preparation of specifications for welded buildings, the accumulation of cost data, the training of designers, the qualification of welders and inspectors, and additional tests of welded joints, which are now receiving attention. Investigations made toward the definite betterment of present conditions are cited and in the appendix are given proposed specifications for the arc-welding of steel buildings, with regard to general application, definitions, quality of structural steel and welding electrodes, welding apparatus, workmanship, qualifications of welders, the proportioning of parts and the protection of steel.

Magnetic Alloys of Iron, Nickel and Cobalt. G. W. Elmer. *Bell System Technical Journal*, July, 1929, pages 435–465.

Paper appeared in Journal of Franklin Institute, May, 1929, pages 583–617. Recent investigations of magnetic properties of

alloys of iron, nickel and cobalt have resulted in the discovery of materials of remarkable magnetic properties previously unknown. In a brief review, early experiments that led to the discovery of these materials and the magnetic properties of the entire field are discussed. Those groups of alloys of outstanding scientific and technical importance such as the permalloys and the perminvars and special heat treatment required for development of special magnetic properties are taken up in detail. A theory is suggested to account for some of the magnetic characteristics, and a few of the practical applications of these materials are described.

Fatigue Studies of Non-Ferrous Sheet Metals. JOHN TOWNSEND AND CHARLES H. GREENALL. *Bell System Technical Journal*, July, 1929, pages 576–590.

A paper presented before the A. S. T. M. Convention, June 24–28, 1929. The paper describes the development of a fatigue testing machine for sheet metals and gives results of fatigue tests on 5 alloys of alpha brass, one alloy of nickel silver, one alloy of phosphor bronze and Everdur. The results indicate that cold work raises the endurance limit but not proportionally to the increase in tensile strength produced by the same cause. Micrographs are shown indicating that fatigue failure of the metals investigated is transcrystalline. Dispersion hardening of alpha brass by nickel silicide increases the endurance limit. The ratio of endurance limit to ultimate strength of these alloys varies from .12 to .36 depending on composition, heat treatment and cold work. These ratios are much lower than similar ratios for steel.

Telephone Apparatus Springs. A Review of the Principal Types and the Properties Desired of These Springs. J. R. TOWNSEND. *Bell System Technical Journal*, April, 1929, pages 257–266.

Paper read at A. S. M. E. Meeting, December 3–7, 1928. This article describes the types of springs employed in telephone apparatus and enumerates the engineering requirements both from the standpoint of mechanics and the quality of materials desired. The chemical and physical requirements of the spring materials are given. The importance of fatigue is emphasized and the endurance limit is given for spring brass, nickel silver and phosphor bronze.

Die **Bestimmung des Austenitgehaltes Durch Messung des Magnetischen Sättigungswertes und die Vorgänge Beim Anlassen Gehärteter Stähle.** ED. MAURER AND K. SCHROETER. *Stahl und Eisen*, June 27, 1929, pages 929–940.

This article discusses the possibility of using the determination of the magnetic saturation values as a means of determining the austenite content of quenched steels. The statement of Mathews that in steels, in so far in fact as a complete hardening effect occurs, a greater amount of hardening austenite is present after oil quenching than after water quenching, was tested by this method. It was determined with the steels investigated, except with 0.95% C, which does not harden through on oil quenching, and with alloy steels which show a large content of hardening austenite after quenching, that Mathews is correct.

Some **Characteristics of Pearlite in Eutectoid Steels.** O. V. GREENE. *Transactions American Society for Steel Treating*, July, 1929, pages 57–76.

Includes discussion. Paper presented before the tenth annual convention of the society held in Philadelphia, October 8–12,1928. Considerable study of rail steels of eutectoid composition is presented. The photomicrographs included show the character of the pearlite in these steels may be explained by the method of N. T. Belaiew which utilizes the space relations of the lamellae. It is shown that the pearlite may be fine or coarse independently of the carbon content. The conclusion is therefore drawn that the character of the pearlite will depend merely on the velocity of cooling through Ar_1. No relation was found between the average grain diameter and the Brinell hardness. The ultimate tensile strength is expressed as a function of the Brinell hardness.

Ultimate Tensile Strength, Pounds per Square Inch =
490 × Brinell Hardness.

The distance between lamellae, Δ_0, is shown to be a function of the ultimate tensile strength,

$$\text{Ultimate Tensile Strength, Pounds per Square Inch} = \frac{39000}{\Delta_0}$$

where Δ_0 is expressed in microns. E. S. C.

On Oxygen Dissolved in Steel and Its Influence on the Structure. MARCUS A. GROSSMAN. *Transactions American Society for Steel Treating*, July, 1929, pages 1–56.

Includes discussion, 15 micrographs. It is shown that in regular pack carburizing (box carburizing), steel absorbs oxygen as well as carbon. The amount of soluble oxygen present in steel appears to affect the microstructure. (The soluble oxygen diffuses readily, and is considered apart from precipitated oxides and non-metallic inclusions.) A high oxygen content seemingly favors solubility of cementite in α-iron, and as a result of this solubility it affords opportunity for cementite to diffuse. Cementite diffusion (and hence agglomeration) seemingly accounts for the phenomenon of "split cementite" in the structures observed in the McQuaid-Ehn test, and also for the structure of boundary cementite in low carbon steels. These structures are characteristic of high oxygen material. Solubility of cementite in α-iron can be indicated on the iron carbon diagram. Since some steels exhibit cementite diffusion while others do not, it is suggested that different iron carbon diagrams can be drawn for different steels varying the diagram to accord with the cementite solubility and hence with diffusion power. Oxygen contents must apparently be considered, and in carburized steels it is the oxygen content after carburization that is significant. E. S. C.

On the Nature of Martensite Crystals. DR. KOTARO HONDA. *Transactions American Society for Steel Treating*, July, 1929, pages 97–120.

Includes discussion Paper presented before the tenth annual convention of the society held in Philadelphia, October 8–12, 1928. X-ray investigation shows alpha and beta martensite exist. These forms were explained by a theory of quenching of ten years' standing. A new theory of the mechanism of tempering of quenched steels is presented, in which the A_1 transformation consists of double or stepped changes, the martensite being an intermediate stage of the transformation from austenite to pearlite, or austenite ⟶ martensite ⟶ pearlite. Resistance-temperature, magnetization-temperature, thermal analysis and thermal expansion data demonstrate that tempering of quenched steels occurs in two steps. A new explanation of this phenomenon is offered. The broadening of the X-ray spectral lines is explained by a deformation of the iron lattice into an immense number of minute tetragonal lattices due to the strain of carbon atoms tending to be precipitated from solution. E. S. C.

Cloudburst Process for Hardness Testing and Hardening. EDWARD G. HERBERT. *Transactions American Society for Steel Treating*, July, 1929, pages 77–96.

Includes discussion. Papers presented before the tenth annual convention of the society held in Philadelphia October 8–12, 1928. Experiment has shown that if a piece of steel be placed in a jet of hard steel balls moving at a high velocity, the balls will rebound from a hard steel surface leaving it unaffected but will roughen a soft surface. By this means the exact shape and location of soft areas may be determined, whereas by present hardness testing methods only one or two selected spots are tested. It is also shown that it is possible to superharden a steel surface artificially by bombarding the surface with hard steel balls. The method is demonstrated as practicable for work hardening the surface of steel, cast iron, brass and other metals. The work hardened surface is shown to be further increased in hardness by annealing to a proper temperature at which the work hardening capacity of the metal reaches a maximum. Equipment is described which is practicable for carrying out these operations. E. S. C.

Electro-Magnetic Testing of Wire Ropes. T. F. WALL. *Iron and Coal Trades Review*, June 14, 1929, pages 907–8.

An abstract. An ingenious method for detecting flaws by electromagnetic means is described. Two formidable difficulties are encountered: (1) for practical reasons, no coil which actually links the ropes can be used; and (2) the flaw to be detected does not break the surface of the rope. Points discussed are: causes of rope failure, rope testing magnet systems, the necessity of using a.c. for satisfactory testing, the principles on which flaws are detected, rope-testing equipment at Hatfield Main Colliery, indicating and recording apparatus, low frequency supply and results of tests on a rope with internal flaws. Discussion by the Midland Institute of Engineers at Sheffield. Iron & Coal Trades Review, June 21, 1929, pages 936–7. Discussion brought out: limitations of the apparatus, the question of delicate adjustment, practical difficulties in application, and the value of the apparatus for locked-coil ropes and the author's reply to the discussion. The discussion was not completed. W. H. B.

Der Einfluss von Wismut Auf Das Mechanische Verhalten von Blei. O. BAUER. *Mitteilungen der deutschen Materialprüfungsanstalten*, Heft 3–4, 1929, pages 49–50.

Bauer made alloys of lead with different amounts of Bi up to 2%. The tests are described and the results given in a diagram, which shows that the bending strength is considerably reduced even by very small additions of Bi, while the Brinell hardness is considerably increased. HA.

Prüfung Der Korrosionsbeständigkeit von Alcladblechen. ERICH RACKOWITZ AND ERICH K. O. SCHMIDT. *Luftfahrtforschung*, May 29, 1929, pages 142–152.

132nd Report of the German Research Institute for Aviation, Department of Materials. The report discusses corrosion proofness of Alclad sheets of different thicknesses compared with other

aluminum light metals as tested by a quick test method. The tests are given with all details and numerous photographs of the crystal structure, and indicate that, although corrosion takes place in Alclad, the tensile properties are influenced very little. Only the sheets of 0.8 mm. thickness showed in the quick test and in spraying with salt water a loss of 9% and 15%, respectively, in elongation. Thicker sheets show no losses. The corrosion in Alclad is mainly restricted to the coating layer of aluminum. Changes of surface and losses of weight by corrosion are different for Alclad sheets of different thicknesses. In no cases does peeling of the aluminum coating take place under corrosion. Inter-crystalline corrosion of the sheets at the edges or other places could not be observed. The general conclusion is that the plating of duraluminum with aluminum as is the case with Alclad must be considered as a step forward in the protection against corrosion of refinable aluminum alloys. HA.

Prüfung Der Festigkeitseigenschaften von Alcladblechen. KURT MATTHAES. *Luftfahrtforschung*, May 29, 1929, pages 153–160.

133rd Report of the German Research Institute for Aviation, Department of Materials. The following physical properties were tested: tensile strength, elastic properties, fatigue for alternating stresses, bending strength, drawing properties, behavior of the prospective layer. All tests are tabulated and photomicrographs are reproduced. The elastic limit was found to be 7110 $kg._2/mm.^2$, almost the same as for duraluminum. The bending strength was 9.5 to 10 $kg./mm.^2$ The protective layer sticks until fracture of the metal occurs, it does not peel or tear. Due to its softness, however, it is easily damaged mechanically but without impairing the base metal. HA.

L'Affinité de L'Aluminium Pour L'Oxygène. A. DE BIRAN. *Revue de l'Aluminium et de ses Applications*, April, 1929, pages 777–780.

Excepting the alkali metals and magnesium, aluminum has the greatest affinity for oxygen. The factors determining the oxidation of aluminum are: time, temperature and accessibility of oxygen to the surface, which in its turn depends upon the oxide film previously formed on the surface. In powdered form aluminum is explosive at 925° C. which is higher than for powdered carbon, which explodes at 990° C. An aluminum explosion also gives higher pressures. For this reason, aluminum powder is extensively used in fireworks, in thermit welding, in metallurgical and chemical reduction processes, and in forced oxidation. Another application of instantaneous oxidation is the electric valve phenomenon in electrolytic lightning arresters and in rectifiers. A few disadvantages of the ready and easy oxidation are: the high insulating power of the oxide film, the difficulty of soldering and the refining of scrap. HA.

L'Aluminium en Pyrotechnic. J. BALLY. *Revue de l'Aluminium*, April, 1929, pages 781–785.

Due to its ready oxidation in the powdered form, aluminum is now extensively used in explosives and fireworks, especially due to the fact that aluminum does not give off gaseous combustion products. Bally discusses a few aluminum compositions and their properties when used in fireworks and also gives recipes for their manufacture. HA.

Zugfestigkeit und Härte Bei Metallen. O. SCHWARZ. *Zeitschrift des Vereins deutscher Ingenieure*, June 8, 1929, pages 792–797.

The author discusses the importance of the Brinell test and the efforts to find a relation between tensile strength and hardness also for non-ferrous metals. For the latter, no linear relation of Brinell to tensile strength could be found, even in the same groups of metal except aluminum and its alloys. The conversion factors depend upon the degree of cold-working and vary between 0.3 and 0.6. The applicability for higher temperatures and cast metals is discussed. The paper is illustrated with many diagrams. HA.

Roentgenverfahren zur Räumlichen Ausmessung von Fehlstellen in Werkstoffen. C. KANTNER AND A. HERR. *Zeitschrift des Vereins deutscher Ingenieure*, June 15, 1929, pages 811–816.

The low accuracy and cumbersome application of all methods so far in use have led to the development of the densographic and stereo-metrometric method for the discovery of defective places in materials. These methods can also be used successfully on the finished product without destruction of the latter and the location of the defect exactly determined. All metals permeable to X-rays permit determining: (1) location and extent of the defective places, foreign bodies, cracks, etc., (2) differences in quality of the material with respect to thickness and density, stratification, etc., (3) measurements of such defects. HA.

Corrosion of Metals as Influenced by Surface Films. F. N. SPELLER. *Mechanical Engineering*, June, 1929, pages 431–434.

The paper discusses two different means to resist corrosion: forming of protective surface films and alloying. The first part deals with the fact that there are, as shown in some examples, a number of unstable metals which can be made less corrodible by the formation of protective surface films, that is to say, the metal becomes protected by its own products of corrosion. Aluminum, for instance, possesses a high resistance to atmospheric corrosion by a quickly formed stable oxide film. For alloying those elements are especially qualified which form tenacious stable films in corroding media. In case of iron these elements chiefly are chromium and nickel, which form very resistant oxide films. The formation of solid solutions of these metals with iron favors the resistance to corrosion. By polishing the material, different attacks of corrosion—due to a difference of potential—can be avoided. G. H.

Aluminum for the Automotive Industry. DR. ZAY JEFFRIES. *Journal of the Society of Automotive Engineers*, June, 1929, pages 617–620.

Including discussion. Paper read before Southern California Section Meeting of the Society of Automotive Engineers. The paper outlines the different possibilities of the best suited heat-treatment for cast as well as wrought aluminum alloys, in order to develop the best mechanical properties for various applications. Furthermore the corrosion of these alloys is discussed. A coating of pure aluminum proved best suited to encounter salt water attack. Magnesium Base alloys, very important for aeroplane construction, can now be produced on a large scale. G. N.

Heterogeneity of Steel Ingots. Part 3. Preliminary results of an investigation of the density and viscosity of molten steel near the freezing point. *Rolling Mill Journal*, July, 1929, pages 309–310.

Abstract of a section of the Third Report on heterogeneity of steel ingots. For measuring density Archimedian principle was adopted. A sinker attached to one arm of a balance was weighed in air, mercury, and liquid iron or steel. A vertical tube form furnace, wound with molybdenum wire protected by an atmosphere of cracked ammonia. Sinker consisted of a suspended tungsten rod, protected at its lower end by a short length of alundum tubing, around which an alundum tube was molded. Some of the values obtained were: (1) for carbon content of 0.04%, at 1545–1560 deg. C., a density of 6.95–7.05, using alundum sinker; (2) carbon content of 3.38%–3.65% at 1300–1350 deg. C., a density of 7.23–7.31, using alundum sinker; (3) carbon content of 31.2–3.38 at 1345–1465, a density of 7.17–7.32, using solid tungsten sinker. M. S.

Effect of Nitrogen in Iron and Steel. V. N. SVECHNICOV. *Blast Furnace and Steel Plant*, July, 1929, pages 1021–1026.

Bibliography of 23 references. Reviews investigations made on the harmful effects of nitrogen on the physical properties of steel. Bessemer steel is apt to contain more nitrogen than open-hearth. Its presence affects especially elongation and tends to make steel brittle. In cast iron, liquation of nitrogen is similar to that of phosphorus. In soft Bessemer steel liquation of nitrogen is much higher than in steel with average amount of carbon. When accompanied by liquation of phosphorus their combined effect may produce dangerous results. The blast is probably the source of nitrogen in the converter. In addition to absorption of nitrogen by pure iron, elements such as manganese, silicon and aluminum, usually present in steel, may form nitrides. M. S.

Metallography Simplified for Practical Use in the Shop. Chap. 13. Inclusions, slags and welding seams (concluded). E. PREUSS, G. Berndt AND M. V. SCHWARTZ. *Iron Trade Review*, July 11, 1929, pages 82–83.

Discusses suitability of microscopic examination for determining quality of welds and welding methods. Appendix-Supplementing microscopic testing by other metallographic methods. *Ibid.*, July 25, 1929, pages 196–198. Deals with method of distinguishing different types of steel by means of the spark test, and with the determination of critical points. M. S.

Press Working and Forming of Metals. Part 14. Strain hardening effects in cold worked metals. E. V. CRANE. *Metal Stampings*, July, 1929, pages 505–510.

Discusses the differences in ductility of various metals and the value of physical tests for judging their drawing properties. Metals crystallizing in the "face centered cubic lattice" are most easily cold worked. Tests of particular value are cupping tests, standard tensile test, and microscopic examination. M. S.

Heat Treatment of Cast Iron. F. B. COYLE. *Fuels and Furnaces*, July, 1929, pages 1017–1018.

From paper before American Society for Testing Materials, June 24–28, 1929. Discusses the various stages in heat treatment of cast-iron. (1) Up to 800 deg. F., no change in structure or physical properties occurs. (2) From 800 deg. F. to the critical range, a change in structure occurs, but none in physical properties. (3) From the critical range to the metal point, both structure and physical properties change. M. S.

Photoelectric and Thermionic Properties of Molybdenum. MILES J. MARTIN. *Physical Review*, June, 1929, pages 991–997.

The variation of the photoelectric sensitivity of a molybdenum surface during prolonged heat treatment has been studied over a period of 300 hours of intense heating. Thin ribbons of molybdenum were heated to a temperature of 1325° C. in a high vacuum and the photocurrents produced by the light from a quartz mercury arc were measured with a quadrant electrometer. The photoelectric sensitivity was found to increase as the heating progresses, finally reaching a limiting value. The increase in sensitivity was accompanied by a shift in the wave-length limit from approximately 2600 A. U. to approximately 3800 A. U.

The photoelectric work function of molybdenum was determined from the characteristic wave-length limit of the heat treated surface after a condition of stability had been attained. The value of the work function so determined was 3.22 + .16 volts.

The thermionic work function of molybdenum was determined for the same specimens. The thermionic emission as a function of temperature was plotted logarithmically according to Richardson's equation. The value of the thermionic work function determined from the slopes of these curves was 3.48 + .07 volts. The photoelectric and thermionic work functions were thus found to agree within 0.26 volt.

The variation of photoelectric sensitivity of molybdenum with temperature amounted to approximately 30 percent between room temperature and 1000° C.

Dependence of Electron Emission from Metals upon Field Strengths and Temperatures. R. A. MILLIKAN AND C. C. LAURITSEN. *Physical Review*, April, 1929, pages 598–604.

This paper contains a full presentation of the reasons for believing, contrary to results recently obtained elsewhere, that field currents are only independent of temperature up to about 1100° K., and that at that temperature the energy of thermal agitation begins to assist the fields appreciably in causing the escape of electrons from metals. The precise form of function describing this dependence is not accurately determinable experimentally, but the form originally suggested by the authors fits the facts of observation thus far known satisfactorily, not better, however, than does the theoretical form suggested by Houston.

Magnetic Losses of Iron in High Frequency Alternating Current Fields. JOHN R. MARTIN. *Physical Review*, April, 1929, pages 621–622.

A number of investigators have studied the power loss due to eddy currents and hysteresis in iron when placed in high frequency alternating current fields, but the results obtained are in wide disagreement. Using a new method, the author has investigated the variation of this loss with the frequency for several areas of cross section. The total loss is considered as that due to an equivalent resistance and by measuring the values of this resistance at resonance, the loss may be determined from the I^2R relation. With magnetizing currents of 3, 4 and 5 ampere-turns per cm. the measurements are made on short iron cylinders of various areas of cross section at frequencies ranging from 520 to 968 kilocycles. The loss is found to increase with frequency in the small samples and to decrease with frequency in the larger. At any particular frequency the loss per unit volume is less the greater the area. This is due to the magnetic shielding effects of eddy currents in the large samples and the disagreement between previous investigations may thus be explained.

The specific Heat of Molybdenum from 250° C. to −40° C. D. COOPER AND G. O. LANGSTROTH. *Physical Review*, Feb., 1929, pages 243–248.

By use of a long covered tube in the calorimeter proper of an ordinary Richards adiabatic calorimeter, values for the heat capacities of metals from high temperatures may be obtained, even when the falling body is not protected from radiation losses by a metal jacket. The experimental procedure for such a determination is given. A calorimeter arrangement in which the metal was first partially cooled in the calorimeter and then allowed to come in contact with the water of the calorimeter proved unsuitable as is shown. The specific heats of molybdenum between the temperatures of −30° C. and 300° C. are given by the following equation with an accuracy of about one percent:

$$C_p = 0.0593 + 0.000013\,(T + 40) - 0.0265/(T + 40)^{1.06}$$

Stern's equation, which is linear agrees with the values given between 50° C. and 300° C. Below 50° C. the curve shows a decided bend.

Thermal Conductivity of Lead and of Single and Poly Crystal Zinc. C. C. BIDWELL AND E. J. LEWIS. *Physical Review*, Feb., 1929, pages 249–251.

The thermal conductivities of lead and of single and poly crystal zinc over the temperature range −250° C. to +100° C. determined by a method previously described by Bidwell are reported upon. The thermal conductivity increases for these metals as the temperature is lowered but shows no extraordinary increase at extreme low temperatures as was found for lithium. The single crystal zinc shows about 18 per cent better thermal conductivity than the poly crystal sample. A zinc sample cast in open air showed about 7 per cent poorer conductivity than a sample prepared in the vacuo.

The Influence of Surface Conditions on the Friction of Metals. R. B. Dow. *Physical Review*, Feb., 1929, pages 252–257.

The present investigation, by an improved tilt method, attempts accurately to determine the static coefficient of friction for metallic surfaces under varying surface conditions in different media. The presence and nature of oxide films materially affect the rise of the friction curve; a thin film acting as an abrasive causes the curve to rise, the rate depending on the normal force, until a layer of increased stability is reached. In terms of surface flow this indicates the formation of a vitreous layer. Thick films of certain oxides act as lubricants of great stability. Area of rubbing, shape of surfaces, and dry gases have no influence on u; moist inert gases show a capillary effect, moist active gases destroy the surfaces. u is found to be a linear function of the number of slips of one surface over another.

The Furnace Spectrum of Beryllium. R. F. PATON AND G. M. RASSWEILER. *Physical Review*, Jan., 1929, pages 16–21.

A high-temperature vacuum furnace using tungsten for container, and heating elements as well, has been designed to study the furnace spectra of high melting point substances. The furnace spectrum of beryllium in both absorption and emission has been observed from λ2150A–7000A and over a range of temperature up to 2500° K. The prediction that the beryllium line 2348.62A is the first line of the principal series of singlets for the neutral atom has been successfully confirmed.

An Experimental Study of the Growth of Zinc Crystals by the Czochralski-Gomperz Method. A. G. HOYEM AND E. P. T. TYNDALL. *Physical Review*, Jan. 1929, pages 81–89.

The conditions necessary to grow zinc single crystals of 2.7 mm. diameter and of any desired orientation are determined experimentally. When a constant rate of growth is used and the crystal is initially given the desired orientation by starting it on a suitable nucleus the determining factor for the successful growth of a single crystal rod 10 cm. or more in length is found to be the temperature gradient existing in the column of liquid zinc just below the growing crystal. The appropriate temperature gradient is a function of the orientation of the crystal. It is depicted graphically in a figure which shows the upper and lower limiting curves for the region of successful in growth when the rate of growth is 1.2 cm./min. The lower curve rises from orientation 0 to 45° and falls from 45 to 90°. The upper curve lies slightly above and parallel to the lower curve from 0 to 50°, but then rises very sharply. The shape of this region does not seem such as to be attributed only to variation in heat conductivity with orientation. Attempts to grow crystals outside of the appropriate region result in sudden or gradual changes to new orientations. In the latter the orientation shifts gradually through a considerable range. Illustrations are given of such changes.

Maximum Excursion of the Photoelectric Long Wave Limit of the Alkali Metals. H. E. IVES AND A. R. OLPIN. *Physical Review*, July 1, 1929, pages 117–128.

Earlier experiments have shown that the long wave limit of photoelectric action in the case of thin films of the alkali metals varies with the thickness of the film. A maximum value is attained greater than that for the metal in bulk, which for the majority of the alkali metals lies in the infra-red. The wave-length of the maximum excursion of the long wave limit was first studied for Na, K, Rb and Cs. In each case it was found to coincide with the first line of the principal series, i. e., the resonance potential. If this relation holds for lithium, its maximum long wave limit should be greater than that of sodium. This was tested and confirmed by experiments in which red-sensitive lithium films were prepared, sensitive to 0.6708μ. It is suggested that photoelectric emission is caused when sufficient energy is given to the atom, to produce its first stage of excitation. The identity of photoelectric and thermionic work functions suggests that atomic excitation is the initial process in thermionic emission as well.

The X-Ray Structure and Magnetic Properties of Single Crystals of Heusler Alloy. H. H. POTTER. *Proceedings of Physical Society*, Feb. 15, 1929, pages 135–142.

The X-ray structure of single crystals of Heusler alloy has been examined by the single crystal rotation method. The alloy is found to crystallize as a body-centered cube with lattice constant 2.95 A. U. The aluminum atoms are distributed so as to lie on a face-centered cube with lattice constant = 5.9 A. U. Directional magnetic properties have been studied by a method previously described and have been found to be identical with those of nickel which has a face-centered cubic structure. It is suggested that this may be interpreted as indicating that the manganese atoms—whose positions cannot be determined by X-rays analysis—also lie in a face-centered cubic lattice.

Translations

Negotiations are now under way which will assure the appearance of translations of articles appearing in foreign publications. Under this arrangement, the readers of METALS & ALLOYS *will be assured of receiving in English the best articles at almost the same time as they appear abroad instead of three months to one year later.*

Dilatometric Experiments of the Thermic Effects When Tempering Duraluminum and Its Structural Constituents

By M. Haas and H. Hecker, Aachen, Germany

(*Translated by special arrangement from Zeitschrift für Metallkunde, May, 1929, pages 166–173.*)

This investigation is the starting point of the numerous systematic investigations at the Metallhüttenmännischen Institut of the Technische Hochschule of Aachen for the application of the thermal elongation method in more refined form in the investigation of non-ferrous metals and their alloys. The structural systems of duraluminum: Al–Cu, Al–Mg_2Si, Al–Cu–Mg_2Si, and the German duraluminums 681, 681B and 681B-$^1/_3$, were tested dilatometrically. The results of this evaluation agree with results of the approved working methods.

In the present investigation an attempt was made to elucidate the phenomena in tempering of duraluminum and its structural constituents by means of thermal elongation (differential-dilatometric methods).

The empirically most tested system of duraluminum still requires many scientific investigations to explain the complicated hardening phenomena.

In place of the microscopic method which as yet does not give results, the dilatometric method may be substituted with advantage.

Experimental Set-Up

In the investigations optical differential-dilatometers, based on Chevenard's construction,[1] were used.

At the beginning, the optical Chevenard differential dilatometer was used. The largest part of the investigation, however, was made with the universal dilatometer of Oberhoffer-Esser, which, in principle, works similarly to the Chevenard dilatometer. In construction, the furnace must be mentioned, which is set up at right angles to the camera axis, the illumination permits projecting the curves either straight upon a screen covered with a sensitive silver-bromide paper, or at an angle of 90° on to the plate of the camera. The disadvantage of this double projection is the necessity of a dark room.

Fig. 1 shows a plan of the room, giving the arrangement of the differential dilatometer (*a*) with its accessories. The entire measuring equipment (*b*): furnace control, temperature measurement and lighting switch of the dilatometer and the regulating resistances are located centrally together. In one corner of the room is located a developing table, with a sink (*c*) and a three-color lamp (red, yellow and white) which serves for the immediate development of the photographic plates and papers. Details of the arrangement and manipulation can be found in previous publications.[2]

Tedious and time consuming preliminary tests and numerous calibrating curves were necessary before the test arrangement for light alloys was adjusted and improved.[3] After having recognized and overcome these difficulties, all important light-metal alloys used in industry with their basic systems as also the non-ferrous alloys[4] of the heavy-metal group were investigated.

[1] Details of this dilatometer are given in a paper by Dr.-Ing. Haas, Werkstofftagung, 1927, Berlin. *Zeitschrift für Metallkunde*, Vol. 20 (1928), pages 283–285.

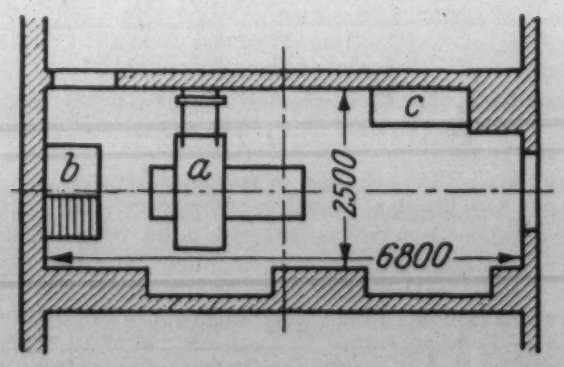


Figure 1—Dilatometric Room at the Metallhüttenmännischen Institut der Technischen Hochschule Aachen. (*a*) Differential Dilatometer, (*b*) Instrument Table, (*c*) Photographic Developing bench.

Working Plan

First the basic constituents Al-Cu and Al-Mg_2Si were tested in the cast and worked state, both unrefined and refined, after that the Al-Cu-Mg_2Si alloys.

Then, pendulum investigations were made of German duraluminum 681-A, 681-B and 681-B-$^1/_3$ both refined and unrefined,[5] i. e., dilatometric curves (pendulum curves) were taken with the same material, for instance, from 20 to 100° C., from 100 to 20° C., from 20 to 300° C., from 300 to 20° C. and so on.

1. Cu-Al

The High Aluminum Part of the System

The Al-Cu system is of special importance among the light metals, since the time it was realized that the Al-Cu alloys could be thermally refined. The intermetallic compound $CuAl_2$ has been recognized as the carrier of the refining and hardening phenomena. The thermal treatment is based upon the variable solid solubility of copper in aluminum at different temperatures. It is, therefore, important to exactly determine the solid solubility of copper in aluminum. By looking through the literature covering the results of these investigations very considerable differences can be noted, which are briefly mentioned below.

1907: Carpenter and Edwards[6] determined microscopically a solid solubility of 5% Cu in Al.

1919: Merica, Waltenberg and Freeman[7] claim, as a result of

[2] Articles by Chevenard, Haas and the Doctor-Thesis by Daweck and Esser, Technische Hochschule, Aachen.

[3] For details see M. Haas, *Zeitschrift für Metallkunde*, Vol. 20 (1928), pages 283–285, and Vol. 20 (1928), pages 300–301.

[4] Paper by M. Haas: "Neuere dilatometrische Untersuchungen," Convention of the Deutsche Gesellschaft für Metallkunde, May, 1928, Dortmund. *Zeitschrift für Metallkunde*, Vol. 21 (1929), pages 58–63; also M. Haas & Denzo Uno: "Über die Vergütung von Standardsilber," *Zeitschrift für Metallkunde*, Vol. 21 (1929), pages 94–96.

[5] All the necessary material was most generously donated by Dr.-Ing. R. Beck, Director of the Dürener Metallwerke.

[6] "On the Properties of Aluminum and Copper," Eighth Report to the Alloys Research Committee, Institution of Mechanical Engineers, Vol. 72 (1907), pages 57–269.

[7] "Constitution and Metallography of Aluminum and Its Light Alloys with Copper and with Magnesium," U. S. Bureau of Standards, *Scientific Paper*, **337**, August, 1919.

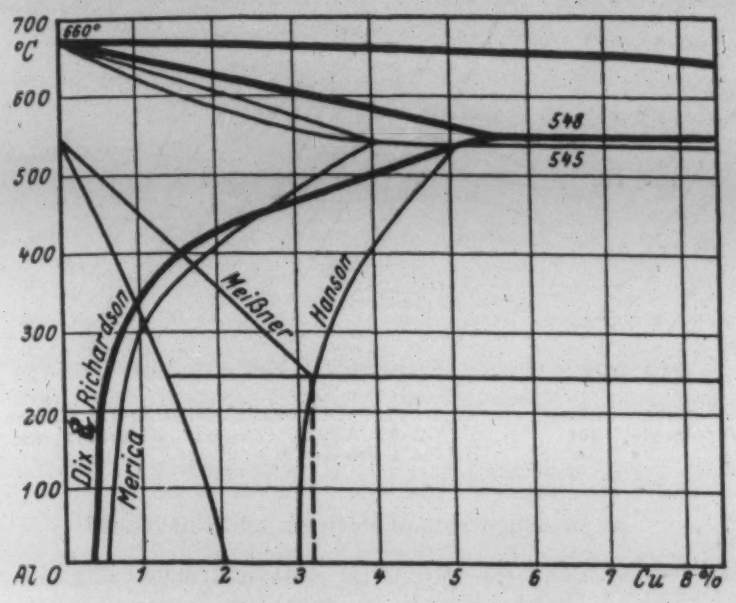


Figure 2—Constitutional Diagram of Al-Cu with the Limiting Values of the Different Investigators

microscopic investigations, a solid solubility of 4% Cu at 500° C., 1% Cu at 300° C. and still less Cu at lower temperature.

1921: Rosenhain, Archbutt and Hanson[8] find microscopically a solid solubility of 5% Cu at 510° C., 3% Cu at 20° C.

1922: Otani and Hemmi,[9] by determining the electric conductivity, find a solid solubility of 1.5% Cu at 420° C. and 4.8% Cu at 520° C.

1926: Meissner[10] develops theoretically, assuming an allotropic form of aluminum at 500° C., a partial diagram with three separate constitutional fields (see Fig. 2).

1926: Dix and Richardson[11] by micrographic methods and the purest starting materials check the solid solubility line and construct a new diagram (see Fig. 2) with a solid solubility of 5.5% Cu at 548° C., 2% at 430°, under 1.25% Cu at 385° C.

The extensively discussed partial diagram Al-Cu in the part high in aluminum aroused a desire to check this by the differential dilatometric method.

If a thermally refined Al-Cu alloy of this composition is slowly heated (tempered) a distinctly increased elongation occurs at a certain temperature which attains a maximum, then changes to a reduction in length, and finally again assumes the normal direction of the original elongation.

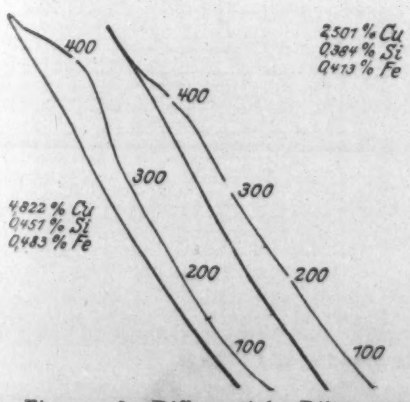
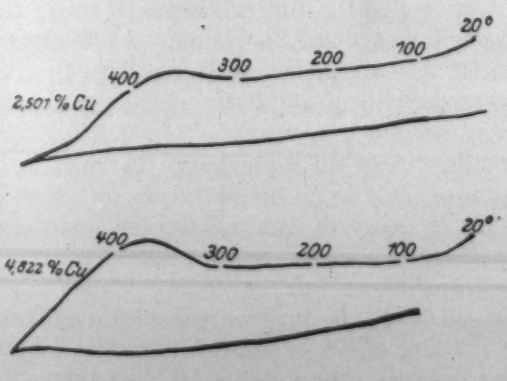


Figure 3—Differential Dilatometer Curves of Refined Cu-Al Alloys. (Comparison Rod: Electrolytic Copper)



Figures 4 and 5—Differential Dilatometer Curves of Refined Cu-Al Alloys. (Comparison Rod: Pure Aluminum)

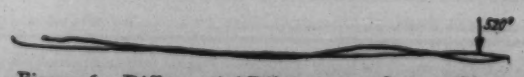


Figure 6—Differential Dilatometer Curve (Chevenard Dilatometer) of a Cu-Al Alloy with 4.8% Cu. (Comparison Rod: Pure Aluminum)

[8] "On Some Alloys of Aluminum," Eleventh Report to the Alloys Research Committee, Institution of Mechanical Engineers, 1921.

[9] "Alloys of Aluminum and Copper," *Journal of Chemical Industry (Japan)*, Vol. 24 (1922), pages 1353–1368.

[10] "Die Veredelungsvorgänge in vergütbaren Aluminiumlegierungen," *Zeitschrift des Vereines deutscher Ingenieure*, Vol. 70 (1926), pages 391–401.

[11] "Equilibrium Relations in Aluminum Copper Alloys of High Purity," *Transactions of the American Institute of Mining and Metallurgical Engineers*, Vol. 73 (1926), pages 560–580.

This phenomenon can be clearly observed in Figs. 3, 4 and 5. Here the differential dilatometric curves of forged Al-Cu with 2.5001 and 4.822% Cu, respectively, are reproduced (the samples were refined by heating at 520° C. and quenching in water). As a comparison rod, pure copper was used for the steep upper curves, purest aluminum for the horizontal lower curves. Naturally, the dilation effects are more distinctly in evidence in the lower curves.

The alloy containing 2.501% Cu begins to show a distinct agglomeration of dispersely distributed Al_2Cu particles at about 300° C. with increased elongation. At 360° C. the process reaches a maximum where solution again takes place, which in turn reaches a maximum at 445° C. at the intersection with the solid solubility line.

The 4.882% Cu alloy has not yet reached the reversing point of the solid solubility line at 500° C., the intersection with this line must therefore lie higher.

The curves of the optical dilatometer produce the phenomena in exactly the same clear and exact manner (see Fig. 6). The distinct reversing point on the solid solubility line at about 520° C. is pointed out.

There, therefore, exists the possibility of determining the solid solubility line and thus the range of the solid solubility of two component systems, by means of the dilatometric method and taking into account the velocity with which the equilibrium adjusts itself.

Such a test is practically reproduced in Fig. 7. The white areas correspond to the areas of the original curves. It can be said here briefly that the dilatometric results extensively agree with the new diagram of Dix and Richardson. The theoretical diagram of Meissner constructed without any experimental basis, which rests on the averred allotrophy of aluminum, has been refuted by the clear experimental results.

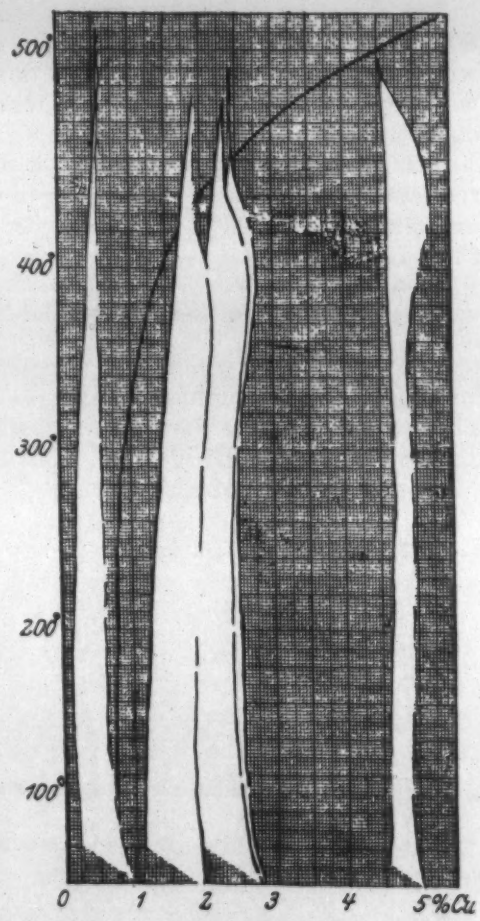


Figure 7—Localized Determination of the Solid Solution Limits in the Aluminum End of the Two Metal Cu–Al System (the Original Areas Are White)

Method of Carrying out the Texts

Pure aluminum of the Aluminiumindustrie Neuhausen (Switzerland) of the following analysis was used:

Fe	= 0.32%	Ca	= Traces
Si	= 0.388%	Al	= remainder
	Cu = None		

For the alloys pure electrolytic copper was used.

With the requisite care, at first a preliminary alloy of 90% Al and 10% Cu was melted in the electric resistance furnace. Under the same conditions a series of trial alloys was made, the composition of these is given in Table 1.

Table 1 Trial Cu–Al Alloys

Sample No.	% Cu	% Si	% Fe
1	0.642	0.473	0.482
2	1.936	0.384	0.330
3	2.446	0.428	0.527
4	2.501	0.384	0.413
5	3.301	0.372	0.328
6	4.822	0.451	0.483

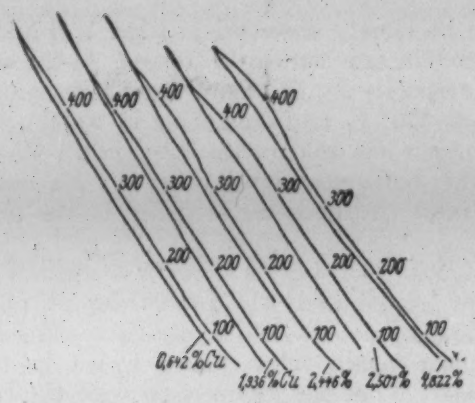


Figure 8—Differential Dilatometer Curves of Cu-Al Alloys (Cast, Unrefined); see Tables 1 and 2

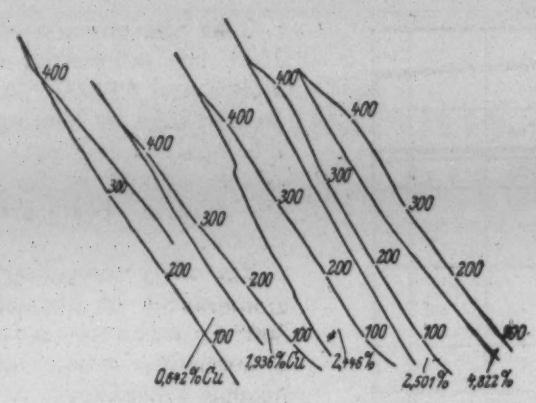


Figure 9—Differential Dilatometer Curves of Cu-Al Alloys (Forged, Unrefined); see Tables 1 and 2

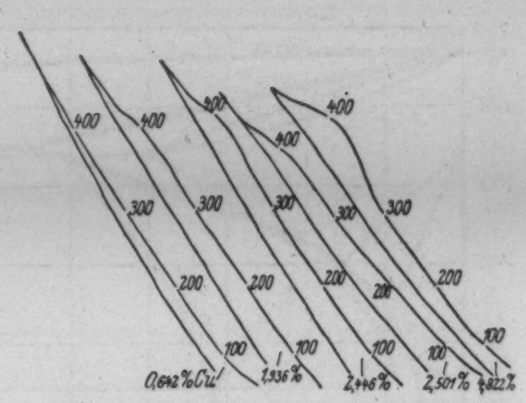


Figure 10—Differential Dilatometer Curves of Cu-Al Alloys (Forged, Refined); see Tables 1 and 2

A few small sample rods were immediately turned from the cast material (cast in preheated ingot molds).

For a second series, the cast pieces were cold worked about 80% by hammering, then soft annealed at 300° C. in agreement with the preliminary treatment of duraluminum. This intimate working as a preliminary treatment was to accomplish a homogeneous character of the material.

A third series of forged samples was first machined to dilatometer rods and then similar to the refining of the duraluminum, annealed for 20 minutes at 520° C. and quenched in water at room temperature.

Evaluation of the Differential-Dilatometer Curves

As was expected the effects (increased amplitude) of the cast unrefined, forged unrefined and forged refined material increased. The few check curves show an excellent agreement with the Cu-Al diagram of Dix and Richardson. See Figs. 8 to 10.

Table 2 gives the important values.

Table 2 Evaluation of Dilatometer Curves of Cu–Al Alloys Represented in Figs. 8 to 10

% Cu	Beginning agglomeration of $Cu-Al_2$	Maximum points of agglomeration	Intersection with the solid solubility line	Remarks
0.642	——	——	——	Linear course of the solid solution field (agrees with the diagram of Merica)
1.936	340°	370°	430°	As Dix and Richardson
2.446	340°	380°	440°	
2.501	310°	375°	450°	
4.822	300°	380°	over 500°	

2. Mg_2Si-Al

The Aluminum End of the System

Contrary to the investigators, who advocate the refining theory of Merica, there exists another group who ascribes the principal refining action to the intermetallic compound Mg_2Si in duraluminum. The investigations of Hansen and Gaylor[12] (British) and the investigations of Honda[13] and Konno[14] show that Mg and Si form an intermetallic compound with about 63% Mg and 37% Si. This compound which is extraordinarily stable is not decomposed when alloyed with aluminum, but occurs as an independent crystal Mg_2Si with a definite solubility of about 1.5% at 590° C. and 0.5% at room temperature. The diagram of the system Mg_2Si according to Hanson and Gayler, Fig. 11, shows a distinct solid solubility curve with

1.6% Mg_2Si at 580° C.
0.9% Mg_2Si at 350° C.
0.52% Mg_2Si at 30° C.

[12] "The Constitution and Age Hardening of the Alloys of Aluminum with Magnesium and Silicon," *Journal of the Institute of Metals*, Vol. 26 (1921), pages 321–359.

[13] "On the Theory of the Hardening of Metals," *Chemical & Metallurgical Engineering*, Vol. 25 (1921), pages 1001–1003.

[14] "An Investigation of Duraluminum," *Science Reports, Tohoku Imperial University*, Vol. XI (1922), pages 269–294.

The Investigations of Portevin and Chevenard

Before describing the individual dilatometric investigations of this system Al–Mg_2Si a dilatometric test of this system by Portevin and Chevenard[15] will be chiefly mentioned.

These two French investigators have tested the following alloys with their well known dilatometer:

Sample No.	% Mg	% Si	% Fe	% Mg_2Si
1	0.95	1.25	——	1.48
2	1.1	0.28	0.35	0.75
3	1.0	0.28	0.87	0.75

The comparison rod in these tests was pure aluminum with 0.13% Si and 0.15% Fe. The samples of No. 1 Alloy were treated as follows.

With a heating rate of 250° C. per hour the samples, which had been soft annealed at about 400° C., were dilatometered in the unrefined state seven times successively from 300° C. gradually rising to 600° C. The respective coolings are carried out in the switched-off furnace at a temperature drop from 500 to 100° C. in one hour. Portevin and Chevenard point out in the evaluation of their pendulum curves 2 to 6, the peculiar deflection which begins at about 250° C. and is explained by the gradual solution of Mg_2Si.

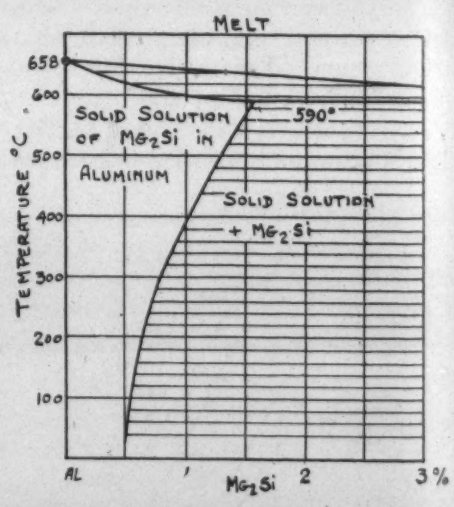


Figure 11—Part of the Constitutional Diagram of the System Mg_2Si–Al According to Hanson and Gaylor

The contraction of the alloys caused thereby was confirmed by the investigations of the Metallhüttenmännischen Institut der Technischen Hochschule of Aachen. According to Portevin and Chevenard the contraction lasts until the entire Mg_2Si has passed over into the solid solution. At the intersection of the solid solubility line the curve again resumes the old direction. Naturally, a vertical drop suddenly occurs near the solidus line due to the alloy becoming pasty.

The course of the cooling curve is remarkable in that it is characterized by elongation due to reprecipitation of Mg_2Si. This progressive expansion is delayed and incomplete, even entirely suppressed at increased cooling rates. After repeated heating and cooling a refining effect (air hardening) takes place even on cooling in air—in this case the furnace was removed from the quartz tubes. This refining effect becomes noticeable in the subsequent dilatometering between 250 and 350° C. as increased elongation.

Portevin and Chevenard especially emphasize that for smaller contents than 1.48% Mg_2Si—corresponding to Alloy No. 1—the dilatometric effects are much less distinct than they are shown in

[15] "A Dilatometric Study of the Transformations and Thermal Treatment of Light Alloys of Aluminum," *Journal of Institute of Metals*, Vol. 30 (1923), pages 329–349.

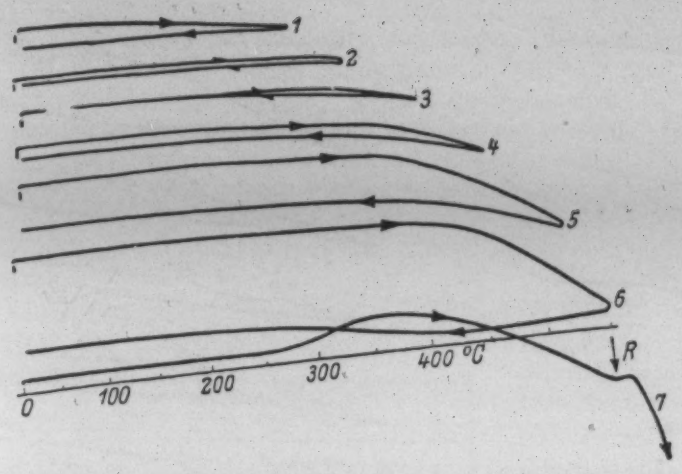


Figure 12—Differential Dilatometer Pendulum Curves of Portevin and Chevenard of a Mg_2Si-Al Alloy with 1.4% Mg_2Si. (Comparison Rod: Pure Aluminum)

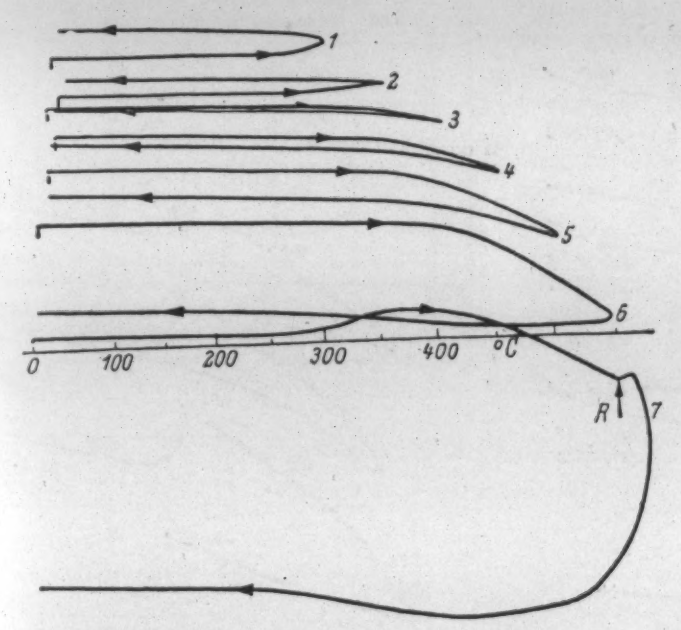


Figure 13—Differential Dilatometer Pendulum Curves of Portevin and Chevenard of a Mg_2Si-Al Alloy with 1.48% Mg_2Si. (Comparison Rod: Pure Aluminum)

Figs. 12 and 13. These alloys contain about 0.75% Mg_2Si and show in their curves that the end point of the solution of Mg_2Si occurs in the Alloy 2 at about 535° C. in the Alloy 3 at about 510° C. Curve 2 again shows the typical dilation above 250° C. due to the annealing effect which the separation of Mg_2Si from the supersaturated solid solution causes. Due to the slow reaction velocity nothing can be seen in the cooling curves, which are perfectly linear and horizontal. For the same reason, the first curve of the sample 2, see Fig. 14, does not show complete solution of Mg_2Si but only the second curve. It shows the influence of extended heating and repeated cooling. The order of the dilatometric effect increases with the contents of Mg_2Si in the samples.

Test Procedure

In the following investigation the system Al–Mg_2Si was tested dilatometrically. At first a preliminary alloy of the following composition was melted in a graphite crucible lined with clay:

20.40% Mg	0.73% Fe
12.01% Si	Balance Al

that is an alloy in which the silicon present is almost entirely bound by the Mg to the intermetallic compound Mg_2Si. By means of this alloy, trial alloys according to Table 3 were melted:

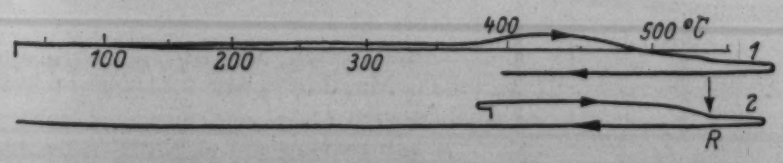


Figure 14—Differential Dilatometer Curves of Portevin and Chevenard. Si-Al Alloys with 1.1% Mg_2Si. (Comparison Rod: Pure Aluminum)

Table 3 Chemical Composition of the Samples from the System Mg_2Si–Al

Test No.	Mg_2Si %	% Si	Fe %
1	0.237	0.124	0.166
2	0.508	0.155	0.171
3	0.829	0.127	0.171
4	1.06	0.144	0.263
5	1.25	0.137	0.213
6	1.674	0.590	0.112
7	2.118	0.134	0.220
8	2.408	0.430	0.213

All samples were preforged and rolled about 80%. After this they were annealed soft at 350° C. and machined to small dilatometric rods.

Some of the rods were dilatometered unrefined while the balance was annealed for 20 minutes at 520° and quenched in water of room temperature. After storing for 6 days these rods were also tested dilatometrically. For all samples of this system a rod of the purest American aluminum was used for comparison.

Evaluation of the Differential Dilatometer Curves

Table 4 Evaluation of the Dilatometer Curves in Figures 15 to 18

Mg_2Si Content in %	Start of Mg_2Si precipitation (contraction)	Intersection line with the solid solubility Unrefined	Refined	Remarks
0.237	—	—	—	Agreement with diagram of Hanson-Gaylor
0.508	—	—	—	linear
0.505	—	—	—	"
0.829	280	310	310	"
1.06	270	400	400	"
1.25	265	408	480	"
1.63	260	—	—	
1.67	260	—	—	Range of solid solution + Mg_2Si
2.118	260	—	—	"
2.408	230	—	—	"

With increasing Mg_2Si contents, these alloys show an earlier precipitation from the supersaturated solution. The values of the intersection with the solid solubility line in most cases coincide with the diagram of Hanson and Gaylor.

3. Mg_2Si-Cu-Al

For further investigations, the combination alloy Al-Cu-Mg_2Si was dilatometrically systematically tested to obtain some idea of the influence of the manganese in the German duraluminum.

The recent investigations of Dix and Keith[16] on the equilibrium diagram of purest Mn-Al alloys have shown a solid solubility of

0.65% Mn at 657° C. in aluminum
0.23% Mn at 550° C. in aluminum
0.14% Mn at 230° C. in aluminum

In the following dilatometer curves only a small deviation can be determined by comparison with the duraluminum curves (see Figs. 19 and 20).

Test Procedure

Three comparison alloys with increasing Cu-contents were synthetically melted.

Three comparison alloys with increasing Cu-contents were synthetically melted

Alloy 1	Alloy 2	Alloy 3
Analysis	Analysis	Analysis
0.556% Mg	0.514% Mg	0.532% Mg
0.401% Si	0.357% Si	0.312% Si
0.921% Cu	3.195% Cu	3.769% Cu
0.212% Fe	0.220% Fe	0.251% Fe

Comparison rod: American pure aluminum.

The unrefined as well as the refined curves show the summation effects of the precipitation of Mg_2Si and $CuAl_2$, respectively.

The curves of the material corresponding to the duraluminum metal show a most thorough agreement with the following duraluminum curves.

[16] "Equilibrium Relations in Aluminum-Manganese Alloys of High Purity," *Proceedings of the Institute of Metals Division of American Institute of Mining and Metallurgical Engineers*, Vol. 74 (1927), pages 315–355.

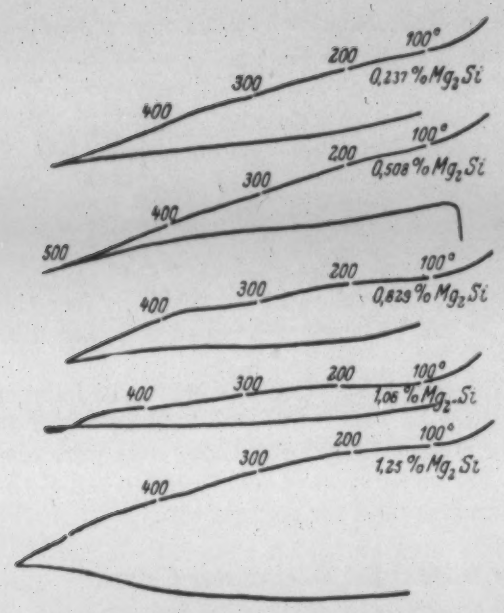


Figure 15—Differential Dilatometer Curves of Mg_2Si-Al Alloys, Unrefined. (Comparison Rod: Pure Aluminum)

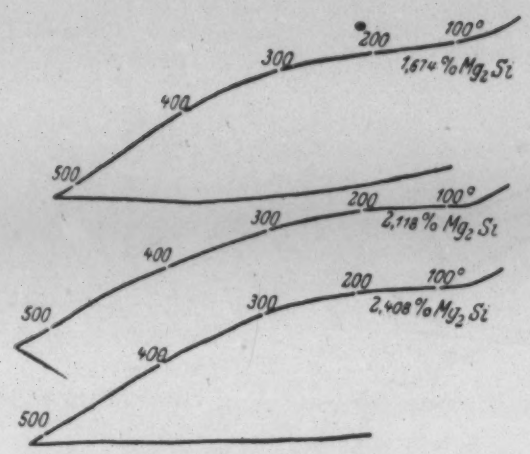


Figure 16—Differential Dilatometer Curves of Mg_2Si-Al Alloys, Unrefined. (Comparison Rod: Pure Aluminum)

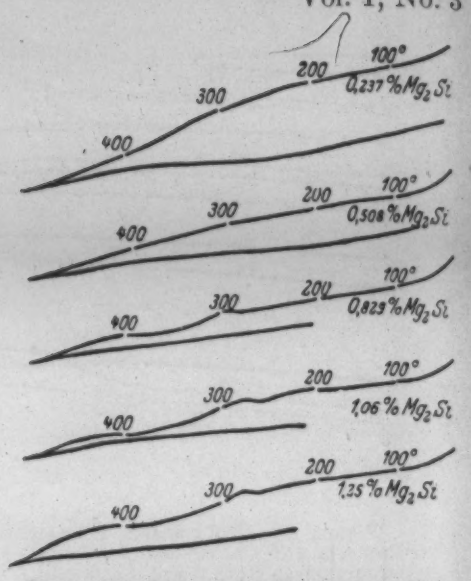


Figure 17—Differential Dilatometer Curves of Mg_2Si-Al Alloys, Refined. (Comparison Rod: Pure Aluminum)

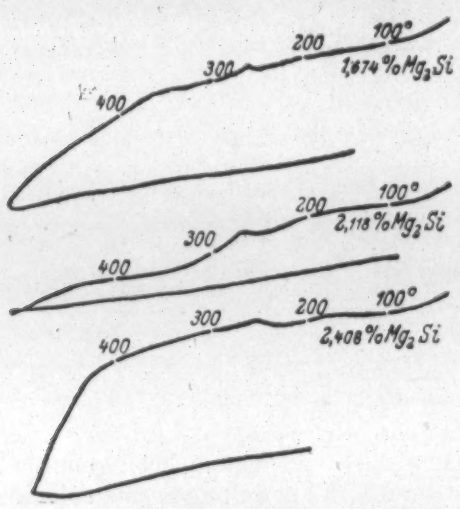


Figure 18—Differential Dilatometer Curves of Mg_2Si-Al Alloys, Refined. (Comparison Rod: Pure Aluminum)

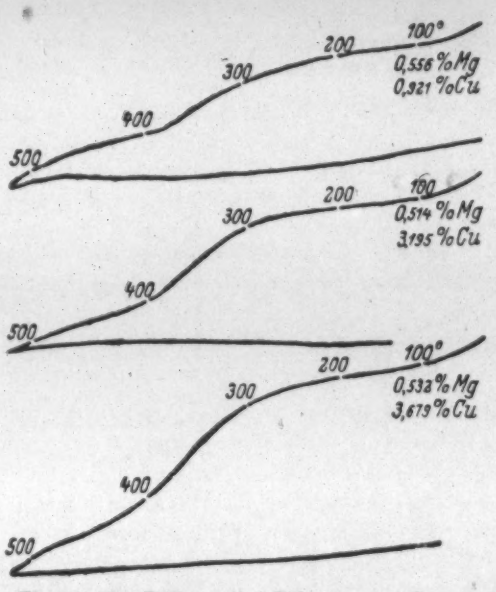


Figure 19—Differential Dilatometer Curves of Mg_2Si-Al Alloys, Unrefined. (Comparison Rod: Pure Aluminum)

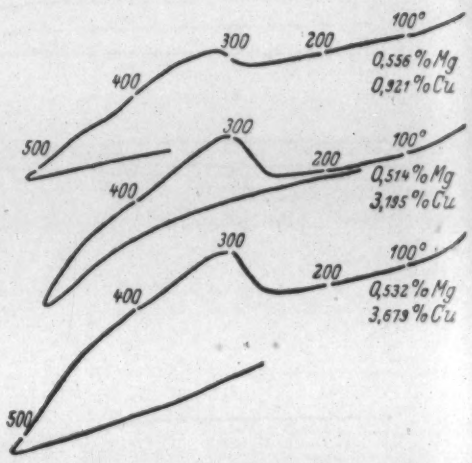


Figure 20—Differential Dilatometer Curves of Mg_2Si-Al Alloys, Refined. (Comparison Rod: Pure Aluminum)

4. Duraluminum

The effects during annealing (tempering) of the duraluminum have so far not been investigated dilatometrically. Seibel Konno[14] has tested with the differential dilatometer samples of duraluminum melted by himself (with 3.5 to 4% Cu, 0.5 to 0.7% Mg, 0.5% Mn). The quenching curves from 500° C. in water showed upon annealing two distinct expansion effects at 210 and 280° C. See Fig. 21.

These effects are explained by the precipitation of Mg_2Si and $CuAl_2$, respectively. Strange to say, in the second annealing the expansion curve shows no effects (Portevin and Chevenard also call attention in their paper[15] to this contradiction by pointing out the 330° C. effect in the resistance measurements).

Very interesting information is also given by the curves of the physical tests of the hot tensile tests on duraluminum 681B, Fig. 22, and of the influence of heating on hardness and tensile strength of duraluminum 681B, see Fig. 23. (These curves were placed at our disposal through the courtesy of the Dürener Metallwerke.)

The following curves, from the investigations of Chuzo Sugiura,[17] who examined the reciprocal effects of volume, the specific gravity, during annealing of samples of duraluminum, are of interest in comparison with our own, (see Fig. 24).

[17] "Untersuchungen über Duralumin," Private publication, Osaka, January, 1926; up to the present only published in Japanese.

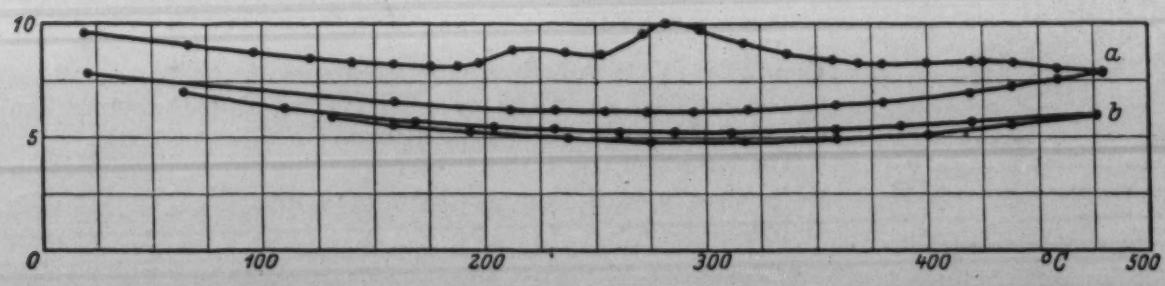


Figure 21—Differential Dilatometer Curves of Duraluminum by Seibei Konno with the Honda Dilatometer, (*a*) First with Refined Duraluminum, (*b*) Second Heating

Analysis of the samples:

(46) 4.01 Cu, 0.37 Mg, 1.18 Mn, 0.76 Fe, 0.56 Si
(47) 3.64 Cu, 0.58 Mg, 1.42 Mn, 0.34 Fe, 0.40 Si

Pre-treatment:

(*a*) Refined 30 minutes at 520° C. and cooled slowly in the furnace. Heated at the testing temperatures about 30 minutes and quenched in ice-water.

(*b*) Refined 30 minutes at 520° C. quenched in ice-water, and artificially aged. Tempered at the testing temperatures.

Evaluation; Slight reduction of density up to 100° C., then an increase up to 175° C., then a sudden decrease up to the turning point at 300°, then again an increase up to 500° C. Sugiura gives no precise metallurgical explanation.

Tests Procedure
Duraluminum 681A. 681B. 681B-1/3

The chemical composition of the samples was as follows:

Duraluminum 681 A: 3.52% Cu, 0.5% Mn, 0.5% Mg, 0.3% Fe, 0.32% Si, balance Al.

Duraluminum 681 B: 4.2% Cu, 0.61% Mn, 0.53% Mg, 0.29% Fe, 0.31% Si, balance Al.

Duraluminum 681 B-1/3: 4.1% Cu, 0.32% Mn, 0.52% Mg, 0.31% Fe, 0.33% Si, balance Al.

A comparison rod of purest American aluminum was used as comparison rod for all duraluminum dilatometer curves.

For each pendulum heating, only one sample rod was used for taking the dilatometer curves of duraluminum, i. e., each test rod was subject to 5, respectively, 4 heatings and coolings.

The maximum temperature of the first heating was 300° for all pendulum annealings. The maximum temperature of pendulum-annealings was increased from heating to heating by 100° C.

The rate of heating in all tests was about 25 minutes for 100° C.

The cooling of the sample rods was carried out in four different ways:

1. In the furnace under current.

Herewith the current was reduced, after having attained the desired temperature (about 520° C.), by 0.25 ampere every 15 minutes. Time of cooling (time between maximum temperature and final room temperature): about four hours.

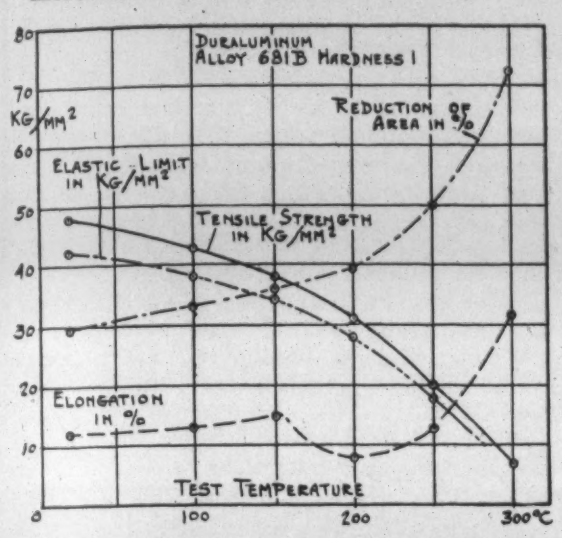


Figure 22—Tensile Tests at Elevated Temperatures of Duraluminum Alloy 681B Hardness

2. In the furnace with the current cut off (current cut off when the desired temperature was reached). Time of cooling about 90 minutes.

3. In air (heating current switched off—furnace removed from quartz tubes). Time of cooling about 15 minutes.

4. In water. (The samples were annealed at 520° C. and quenched in water at room temperature.)

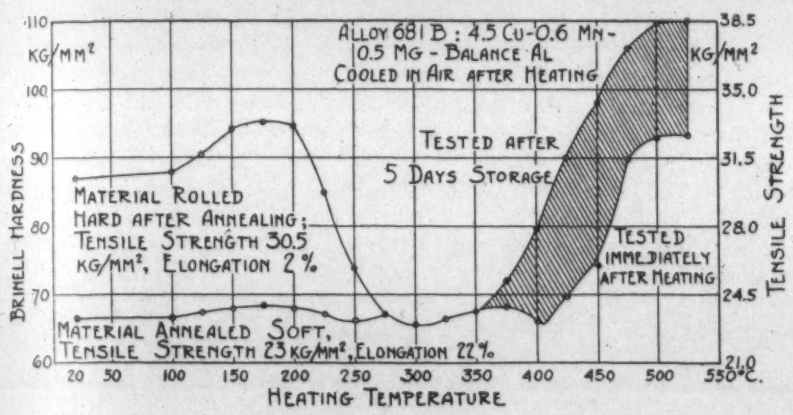


Figure 23—Influence of Heating on the Hardness and Tensile Strength of Duraluminum 681B

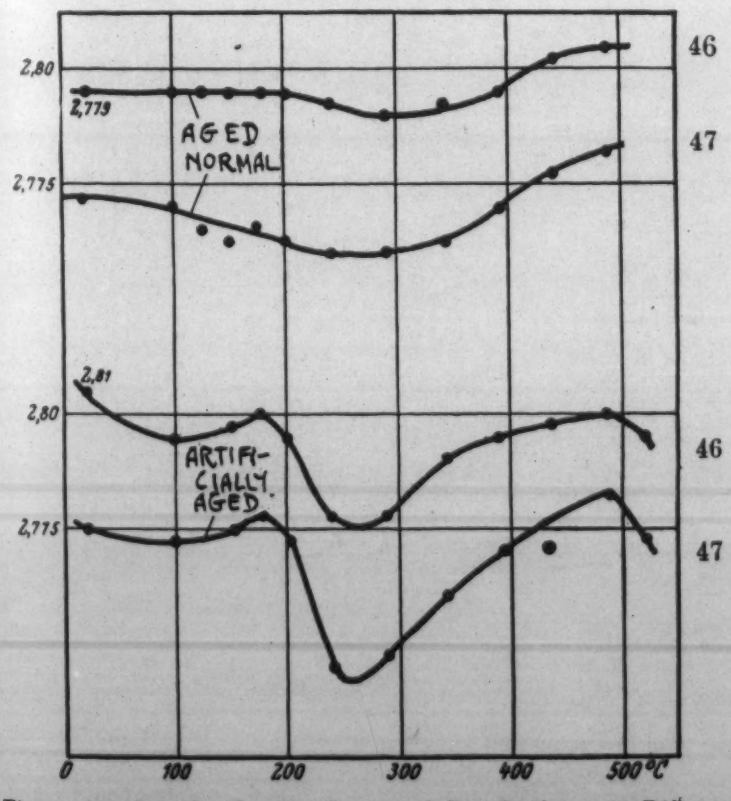


Figure 24—Specific Gravity Curves of Duraluminum at Different Annealing Temperatures According to Chuzu Sugiura

Evaluation of the Tests

I. Following up the investigations of Chevenard and Portevin, the checking of the diagrams of the systems Al–Cu and Al–Mg_2Si showed, as far as can be seen from the dilatometer curves of these systems plotted for the evaluation of the duraluminum curves, an excellent agreement with the results of the tests by Dix and Richardson (Al-Cu) and Hanson and Gaylor (Al-Mg_2Si).

II. In short, it can be concluded from the dilatometer curves (Figs. 25 to 29) of duraluminum 681A, 681B and 681B-$^1/_3$:

(*a*) The three different kinds of duraluminum show correspondingly similar curves in the unrefined as well as in the refined state.

(*b*) The varying contents of manganese in the different duraluminums has only a slight influence on the shape of the duraluminum dilatometer curves.

(*c*) According to the manner of cooling of the samples from the higher temperatures (about 500° C.), a more or less pronounced annealing (tempering) effect is noticeable in the dilatometer curve at the next heating, and this as follows:

1. In the furnace under current: slight annealing effect (dilation) between 300 and 350° C.

2. In the furnace with current off: medium annealing effect (dilation) between 300 and 350° C.

3. In air: pronounced annealing effect (dilation) between 250 and 350° C.

4. In water: very pronounced annealing effect (dilation) between 250 and 300° C.

Actual practice confirms the evaluation of the annealing and corresponding hardening effects of 3 and 4. The values of strength of duraluminum refined according to method 4 are about 30% higher than those of duraluminum refined according to method 3.

(*d*) In all duraluminum curves, the heating and cooling curves do

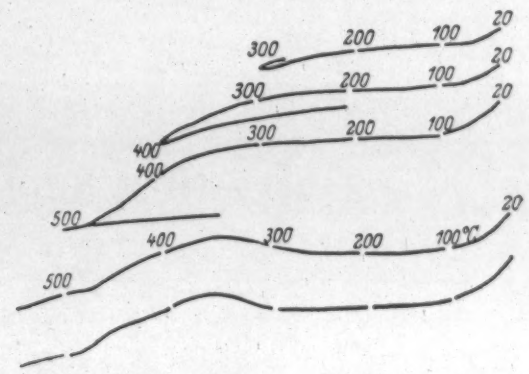


Figure 25—Differential Dilatometer Pendulum Curves of Duraluminum 681A, Unrefined. (Comparison Rod: Pure Aluminum)

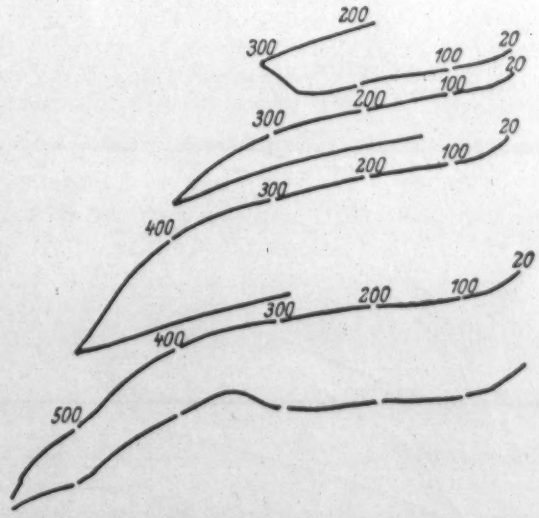


Figure 26—Differential Dilatometer Pendulum Curves of Duraluminum 681A, Refined. (Comparison Rod: Pure Aluminum)

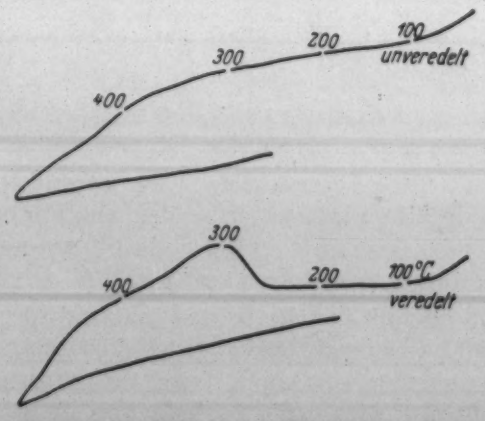


Figure 27—Differential Dilatometer Pendulum Curves of Duraluminum 681B. (Comparison Rod: Pure Aluminum)

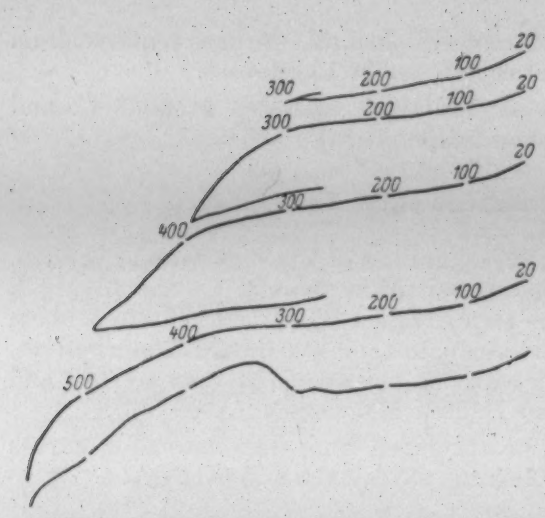


Figure 28—Differential Dilatometer Pendulum Curves of Duraluminum 681B-1/3, Unrefined. (Comparison Rod: Pure Aluminum)

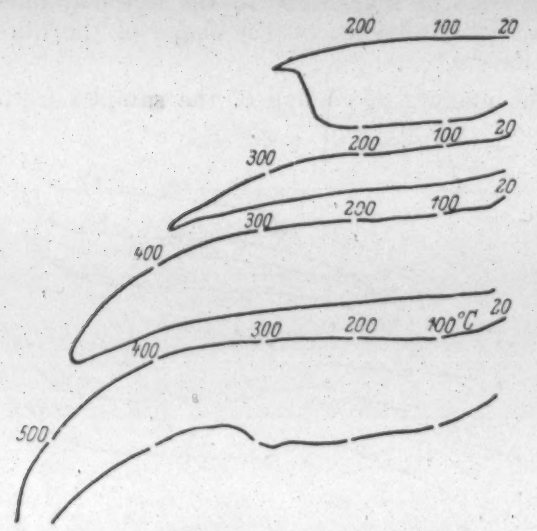


Figure 29—Differential Dilatometer Pendulum Curves of Duraluminum 681B-1/3, Refined. (Comparison Rod: Pure Aluminum)

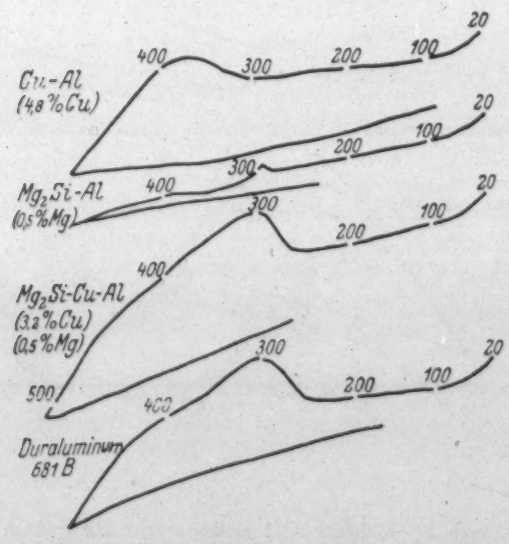


Figure 30—Comparison of the Dilatometer Curves of Duraluminum and Its Constituent Components

not coincide (irreversible). This means that the quantities of Mg_2Si and $CuAl_2$, respectively, dissolved during heating, corresponding to the cooling passing through slight dilation, have only been precipitated in part during cooling. A confirmation of this is found in the dilatometer curves of the duraluminum pendulum annealings.

(*e*) The dilatometer curves of the unrefined duraluminum samples at 480 to 520° C. show an indentation (return from the contraction starting at about 220° C. in the original direction) as an indication of the end of the Mg_2Si and $CuAl_2$ passing into solution in aluminum.

(*f*) The deflection of the dilatometer curves of duraluminum occurs at about 550° C. (plastic limit).

III. From the tabulation of the curves for Al-Cu, Al-Mg_2Si, Al-Cu-Mg_2Si and duraluminum, it is quite obvious that without doubt the reason for the dilation in the temperature range between 250 and 350° C. is principally a precipitation of Mg_2Si from the supersaturated solution, see Fig. 30.

IV. The dilatometric investigation of duraluminum gives the following results for actual practice:

(*a*) A maximum annealing temperature of 520° C. is sufficient to transform all hardening components into solid solution.

(*b*) A higher annealing temperature is a disadvantage as, after reaching the plastic limit, a deformation of the annealed material is unavoidable. (Foreign tests on automobile disc wheels with annealing temperatures up to 560° C. have shown this.)

(*c*) In service the refined material must not be heated above 200° C. (connecting rods, pistons for internal combustion engines). (Precipitation of Mg_2Si from the supersaturated solution—loss of physical properties.) Reduction in strength at elevated temperatures (compare the comparison curves of the physical properties at elevated temperatures).

Recovery of Metals from Secondary Sources in 1928

The value of certain non-ferrous metals recovered from secondary sources in 1928 is reported to the United States Bureau of Mines, Department of Commerce, as $277,623,500, which is $21,271,500 more than in 1927. This increase in total value, according to J. P. Dunlop, who compiled the figures, was due mainly to larger recoveries of copper, brass, lead and nickel, and to the higher average price of copper in 1928, for the average prices of lead, zinc and tin were considerably less in 1928 than in 1927. There were large gains in the quantity of secondary copper, lead and nickel in 1928, and small increases in the quantity of secondary zinc and aluminum, and small decreases in the quantity of tin and antimony. The quantity of copper, including that in brass, increased more than 46,000 tons.

There was a continuation of the large shipments of scrap copper and brass to Europe. In 1927 the combined exports were 68,706 short tons, and in 1928, 70,146 tons. The combined imports of copper scrap and brass scrap in 1928 were about 11,400 tons, mainly from Canada and Latin American countries.

The main increase in lead was in the output of secondary pig lead at smelters which treat mainly ore. The increase at these plants was about 17,500 tons, while at regular secondary plants the increase was only about 1500 tons. Secondary lead recovered in alloys increased 13,600 tons.

Zinc recovered by redistillation increased nearly 6000 tons, while that recovered by sweating and remelting was about the same in 1928 as it was in 1927. The exports of zinc dross decreased 1300 tons, but the quantity used in zinc dust, lithopone, and zinc chloride increased about 9000 tons.

The detinning plants treated a larger quantity of clean tin plate clippings in 1928 than in 1927, but the recovery from such clippings was less. It is reasonable to assume that the efficiency of the detinning plants has not decreased in the last ten years, yet the yield of tin per long ton of tin plate clippings (according to reports filed with the Bureau of Mines) has declined from 36.27 pounds in 1918 to 30.3 pounds in 1928. Very few old tin coated containers were treated in 1928, for the much lower prices of tin made the handling of them unprofitable. About two-thirds of the recoveries at detinning plants were as tin content in tin tetrachloride, and tin oxide.

The profits in most lines of secondary metal recovery were larger in 1928 than for several years, and operations were on a sounder and less speculative basis. The range in metal prices was not large and secondary metal dealers and smelters relied more on ordinary profits of buying and selling. There seems to be, however, need of improved business methods since profit in handling certain scrap metals and drosses is said to be very small.

Secondary metals of certain classes recovered in the United States, 1927–28

	1927		1928	
	Short tons	Value	Short tons	Value
Copper, including that in alloys other than brass	290,000	$75,980,000	325,000	$93,600,000
Brass scrap remelted	286,000	60,516,400	302,000	70,935,200
Lead as metal	119,000	34,776,000	138,000	38,797,600
Lead in alloys	157,000		170,600	
Zinc as metal	64,800	9,881,600	70,700	10,162,600
Zinc in alloys other than brass	12,400		12 500	
Tin as metal	8,800	46,302,100	8,200	35,678,300
Tin in alloys and chemical compounds	28,100		27,600	
Antimony as metal	1,700	3,060,300	745	2,451,400
Antimony in alloys	10,700		11,155	
Aluminum as metal	23,000	23,469,600	24,500	22,848,400
Aluminum in alloys	23,200		23,300	
Nickel as metal	480	2,366,000	635	3,150,000
Nickel in nonferrous alloys and salts	2,900		3,865	
	.....	256,352,000	.....	277,623,500

Secondary copper recovered, 1927–28, with imports and exports of brass and copper scrap, in short tons

	1927	1928
Copper as metal	201,000	230,000
Copper in alloys other than brass	89,000	95,000
	290,000	325,000
Copper from new scrap (not including brass)	57,000	68,000
Copper from old scrap (not including brass)	233,000	257,000
	290,000	325,000

Brass scrap remelted:		
New clean scrap	134,000	147,000
Old scrap	152,000	155,000
	286,000	302,000
Copper content of brass scrap (averaging 70 per cent copper):		
New scrap	93,800	102,900
Old scrap	106,400	108,500
	200,200	211,400
Total secondary copper (including copper content of brass scrap):		
From new scrap	150,800	170,900
From old scrap	339,400	365,500
	490,200	536,400
Brass scrap imported	3,993	6,077
Scrap copper imported	3,739	5,304
Brass ingots, scrap, and old exported	45,997	42,413
Scrap copper exported	22,709	27,709

Secondary lead recovered, 1927–28, in short tons

	1927	1928
Secondary lead recovered by smelters that treat mainly ore	38,424	55,930
Secondary lead recovered by smelters that treat only scrap and drosses	80,576	82,070
	119,000	138,000
Secondary lead recovered in remelted alloys:		
Lead content of antimonial lead scrap treated at regular lead smelters	8,553	11,063
Lead content of drosses and scrap alloys treated at secondary smelters	148,447	159,537
	157,000	170,600
Total secondary lead recovered	276,000	308,600

Refined primary lead produced, 1927–28, in short tons

	1927	1928
Refined primary lead produced in the United States:		
From domestic ore	668,320	626,202
From foreign ore and base bullion	128,210	154,869
Lead content of antimonial lead from foreign and domestic ores and bullion treated at regular smelters	21,611	29,626

Secondary zinc recovered and products made from zinc dross, skimmings and ashes, 1927–28, in short tons

	1927	1928
Secondary zinc recovered by redistillation	42,784	48,666
Secondary zinc recovered by sweating, remelting, etc.	22,016	22,034
Total zinc recovered unalloyed	64,800	70,700
Zinc recovered in alloys other than brass	12,400	12,500
Zinc recovered in brass (estimated)	63,200	66,000
Zinc dust made from zinc dross	4,850	6,208
Zinc dross used for zinc dust (estimated)	5,700	7,200
Zinc concentrates and ore exported	46,716	4,518
Zinc dross exported	4,451	3,143
Lithopone made from zinc skimmings and ashes	54,214	61,665
Secondary zinc content of lithopone	10,873	12,186
Zinc chloride made from zinc skimmings, ashes, etc.	40,107	44,057
Zinc content of zinc chloride made from zinc skimmings, etc.	8,824	9,692
Zinc content of zinc sulphate made from zinc skimmings, ashes, etc.	720	771

Secondary antimony recovered in, primary antimonial lead produced in, and antimony imported into the United States, 1927–28, in short tons

	1927	1928
Secondary antimony in antimonial-lead scrap smelted at regular smelters	1,039	1,355
Secondary antimony recovered at secondary smelters	11,361	10,545
	12,400	11,900
Primary antimonial lead produced at regular smelters	24,347	33,058
Antimony content of primary antimonial lead	2,736	3,432
Antimony imported in ore, as metal or as oxide or salts	14,786	15,720
Exports of foreign antimony, antimony regulus or metal	.....	599

Secondary aluminum recovered, 1927–28, in short tons

	1927	1928
Secondary aluminum recovered unalloyed	23,000	24,500
Aluminum recovered in alloys (mainly No. 12)	23,200	23,300
	46,200	47,800

Primary aluminum produced, imported, and exported, 1927–28

Value of primary aluminum produced in the United States	$39,266,000	$47,899,000
Aluminum (crude and semicrude) imported for consumption ..... pounds	62,575,222	38,847,007
Aluminum (crude and semicrude) exported ..... pounds	14,522,560	15,728,281

Secondary tin recovered, 1927–28

	1927	1928
Tin recovered as pig tin ..... short tons	8,800	8,200
Tin recovered in alloys and chemical compounds ..... short tons	28,100	27,600
	36,900	35,800

Clean tin-plate scrap treated at detinning plants ..... long tons	198,600	204,200
Old tin-coated containers treated ..... long tons	12,824	500
Metallic tin recovered at detinning plants ..... pounds	2,288,000	1,754,549
Tin content of tin tetrachloride, tin bichloride, tin oxide and tin crystals made at detinning plants ..... pounds	4,462,000	4,433,751
Total tin recovered at detinning plants ..... pounds	6,750,000	6,188,300
Tin tetrachloride, tin bichloride, tin oxide, and tin crystals made at detinning plants ..... pounds	9,882,000	9,183,943
Average quantity of tin recovered per long ton of clean tin-plate scrap ..... pounds	32.9	30.3
Average quantity of tin recovered per long ton of old tin-coated containers ..... pounds	16.24	4.0

Tin (metal) and tin concentrates (tin content) imported into the United States, 1927–28, in short tons

	1927	1928
Tin imported as metal	79,679	87,327
Tin concentrates imported (tin content)	137	146

Secondary nickel recovered, 1927–28, in short tons

	1927	1928
Nickel recovered as metal	480	635
Nickel recovered in nonferrous alloys and salts	2,900	3,865
	3,380	4,500

Primary nickel produced, imported, and exported, 1927–28, in short tons

	1927	1928
Nickel produced as a by-product from the electrolytic refining of copper at domestic refineries	860	522
Nickel imported for consumption in the United States as nickel, or in nickel ores and matte, oxide and alloys	20,489	34,664
Nickel, monel metal and other alloys exported	1,054	1,175

Department of Commerce

Calendar of Meetings

American Welding Society, National Fall Meeting, Cleveland, Ohio, September 9 to 12.

American Institute of Mining & Metallurgical Engineers, Iron & Steel Division, National Fall Meeting, Cleveland, Ohio, September 9 to 12.

American Institute of Mining & Metallurgical Engineers, Institute of Metals Division, National Fall Meeting, Cleveland, Ohio, September 9 to 13.

American Society for Steel Treating, Eleventh Annual Convention and National Metal Exposition, Public Auditorium, Cleveland, Ohio, September 9 to 13.

American Chemical Society, 78th Meeting, Minneapolis, Minn., September 9 to 13.

American Society of Mechanical Engineers, Iron & Steel Division, National Fall Meeting, Cleveland, Ohio, September 11 to 13.

American Electrochemical Society, Pittsburgh, Pa., September 19 to 21.

Technical Association of the Pulp and Paper Industry, Richmond, Va., and Washington, D. C., September 24 to 27.

Society of Industrial Engineers, Sixteenth National Convention, Cleveland, Ohio, October 23 to 25.

The Fuller Lehigh Company announce the development of a superior grade of chilled iron, which will be known as ELVERITE in tribute to J. S. Elverson, who for more than 25 years has specialized in their chilled-casting work. Mr. Elverson was born in Camden, N. J., in 1865; Alma Mater, University of Pennsylvania, Class of '87; Degrees, B.S. and E.M.; Fraternity, Psi Upsilon (Charter member); and successively: On second geological survey of Pennsylvania; Ore surveys in Pennsylvania and Virginia; Ore Agent for Crane Iron Works; President, Catasauqua Manufacturing Company; Manager of Oxford mines and furnaces of Empire Steel & Furnace Company; President, Lehigh Foundry Company; Special Agent, Naylor & Company; Metallurgist, Fuller Lehigh Company.

Book Reviews

Handbuch der Eisen-und Stahlgiesserei. Vol. 3. Schmelzen, Nacharbeiten und Nebenbetriebe. Edited by C. GEIGER in cooperation with O. BAUER. Julius Springer, Berlin, Germany, 1928. 747 pages, 967 figs. Price, 68.50 R. M.

Following the second volume of this treatise published in 1927, the present volume deals, as the title already indicates, with melting subsequent treatments, and auxiliary operations. The present volume is supplemented by the addition of numerous innovations of recent years which partly have been caused by the extremely keen competition that characterizes the world-market in an increasing degree. It was clear that a new edition had to take into account this development to the largest degree. In the first section, C. Irresberger describes in detail his treatment of melting in the crucible discussing the melting in furnaces without crucibles for the first time and the economy of the different methods of heating crucibles. The second part, "Melting in Cupolas," is by the same author. No reference is made to recent large cupola installations which operate, similar to the more recent blast-furnace charging arrangements, with skip hoists and charging cars and charging buckets. Further, the installations for desulphation and degasing of iron are discussed and also the different methods for making high-grade cast-iron. The third section, "Melting in the reverbatory furnace," has been re-treated by Dr.-Ing. E. Schnetz. Besides the different furnace types, economical questions and the chemical occurrences in hearth-melting are thoroughly discussed. Also the section, "Melting in open-hearth furnaces" by Dr.-Ing. C. Schwartz is now treated very carefully. The designer will find indications for the building of an open-hearth plant which especially takes into account the important conditions of transport. Questions of heating, heat calculations and management of operations are discussed according to their importance. The fifth section, "The small converters," by Max Escher, has been adapted to recent improvements. The sixth section, however, "Melting in electric furnaces," by Dr.-Ing. Karl Dornhecker, has been treated very thoroughly according to the importance which the electric melting has gained especially after the war. The discussion of the electrical part of such plants is valuable for the metallurgical engineer, for the foundryman the discussion of the advantages and disadvantages of the electric furnace, for melting of high-grade cast-iron is of interest. Dr.-Ing. R. Stotz replaces the late Prof. Dr.-Ing. P. Oberhoffer and treats in the seventh part, "Malleable iron," the melting of malleable iron in various types of furnaces and according to different methods. The author did not restrict himself to a discussion of purely practical conditions but also offers under the heading, "Annealing operations," a clear picture of the theoretical understanding so far attained. The eighth section, "The cleaning of castings," by Prof. Dr.-Ing. U. Solise, brings a new cleaning method with the water-jet and detailed information on arrangements for dust exhaustion for sand-blasting, which matter deserves careful attention on account of the health of the workman. In the ninth part, "Treatment of the surface and refining of cast-iron wares," by C. Irresberger, is mentioned calorizing and the Schoop metal-spraying process. The two following sections 10 and 11, "Heat treatment of steel castings" by Dipl.-Ing. Fr Maertens and, "Welding of cast iron and steel castings," by H. Witte, are a welcome enlargement of the new volume. In the former, the important question of heat-treatment of cast steel is discussed in its physico-chemical principles and its influence on structure and properties of this extremely important material. Not less important, especially for the operating engineer, is the other part on "Welding of cast-iron and steel castings" which gives a concise survey on the most important welding methods and their applications. The twelfth section, "Preparing and mixing of molding materials," by Prof. Ad. Widmaier, brings only lesser innovations in the preparation of sand which may become important. The last, thirteenth section, "Patterns and their manufacture including cores and jigs," by Leonard Treuheit, has been enlarged by the discussion of the most important tools and devices for wood working. —G. NEUENDORFF.

Impurities in Metals. BY COLIN J. SMITHELLS. John Wiley & Sons, Inc., New York, 1928. Cloth, 157 pages, 166 figs. Price, $5.00.

This book is of practical value to users and manufacturers as well as advanced students of metallurgy.

The following important chapters are included in the contents: Methods of Studying the Structure of Metals; X-rays and the Structure of Metals; The Structure of Pure Metals; The Structure of Alloys; The Influence of Minor Constituents on Structure; The Influence of Minor Constituents on the Mechanical Properties of Metals; The Influence of Minor Constituents on the Electrical Properties of Metals; The Influence of Minor Constituents on the Corrosion of Metals.

Ample illustrations, tables and charts serve to make clear the text. The reviewer calls attention to a correction in line 13, page 54; the sense seems to require "liquid" instead of "solid."—RICHARD RIMBACH.

Foundry Practice. BY R. H. PALMER. Fourth edition. John Wiley and Sons, Inc., New York, 1929. 450 pages, 267 figs. Price, $3.30.

The book has been written by a man of considerable practical experience. It covers the whole foundry practice, all kinds of molding, handling sands, recent development of molding machines, treating and cleaning of castings, cupola and reverberatory furnace operations, brass melting and foundry equipment, in all their practical details.

The book is plainly written and is not intended to be a scientific treatise. It seems that the metallurgical side of foundry practice did not receive the consideration it deserves. This appears to result in some disadvantages in as far as considerable improvements have been offered during the last years along these lines, which tend to show how important the composition of casting materials and their treatments are for the production of first-class castings.

Whoever recommends this book to students should be careful to draw their attention to errors, which can be observed here and there. Manganese, for instance, is not a metalloid and alloying materials are by no means impurities. However, these errors will not seriously impair the value of the book. It will fulfill its mission in the proper place.—G. NEUENDORFF.

Study of Chromium Plating. BY R. SCHNEIDEWIND, Dept. of Engineering Research, Univ. of Michigan, Ann Arbor, Mich., 1928. 141 pages. Price, $1.00.

This is the complete account of the research work on chromium plating undertaken for the Detroit Edison Co. The interrelation of all the important variables is explained by means of diagrams and tables. This is without question the most comprehensive and advanced treatment of chromium plating yet compiled under one cover. A review of all significant literature and an extensive bibliography are included.—M. B. RIMBACH.

Tin—Salient Facts and Opinions. BY J. A. L. GALLARD and MURRAY STUART. Mining Publications, Ltd., London, England, 1929. Cloth 5 × 7½ inches, 46 pages. Price, 2 s. 6 p.

This booklet concerns itself with the financial and general aspects of tin, discussing such factors as price stabilization, America and tin, as well as the advocacy for tin shares as investments in the United States. Financial information on a number of British-controlled companies producing tin is given. Part II is a short section on geology and mining of tin. Part III discusses the possible effect which the American Tin Trade Association will have on the compilation of those statistics for the protection of the industry from the violent fluctuations for which it is notorious.—RICHARD RIMBACH.

Some Technical Aspects of the Manufacture of Steel Sheets and Tin Plates. By C. A. Edwards. The Welsh Plate and Steel Manufacturers Association, Swansea, England, 1928. 94 pages.

This book is the result of research on sheets, made by the author and his co-workers in the Metallurgical Department of the University of Swansea. After a brief introduction on the internal make-up of the metals, the influence of the crystal size on the tensile test is considered. Short references are then made to the transformations occuring on heating and cooling low carbon steel. In many cases, the magnification of the micrographs is not given. After the manufacture of the steel and hot rolling are briefly touched the pickling and annealing is considered in detail. In these sections are given the most important test results of the work of the author on the influence of hydrogen on the development of pickling blisters, on the effect of pickling additions and on the influence of the annealing temperature on the physical properties and the structure of hot and cold rolled sheets.—Richard Rimbach.

Ueber die Anlassvorgänge in Abgeschreckten Chrom-und Manganstählen. By Hans Goerisch. Julius Springer, Berlin, Germany, 1928. 35 pages, 27 figs. Price, 3.60 R. M.

The Metallurgical Research Institute of the Technische Hochschule, Berlin has lately published a series of publications on the question of the occurrences in annealing hardened steel which are conspicuous by their comprehensive and thorough experimental work. The latest of these publications is a report by Hans Goerisch on the occurrences during drawing (tempering) of quenched chromium and manganese steels. With a sensitive dilatometer the author tests the influence of chromium and manganese on the temperature location, size and velocity of the individual phenomena under which the return of the unstable hardening structure equilibrium in tempering takes place. The investigation was extended to steels with a carbon contents of 0.1 to 1.9% and chromium of 0.5 to 14%, further with a contents of 0.7 to 1.1% C and 0.3 to 10% Mn. In all cases the existence of the known tempering stages proper could be observed, i. e., a steel without alteration of length could not be found. However, location and size of these alterations bear a very definite relation to the composition of the steel. The first reduction in length in the vicinity of about 100° C. and the second at about 280° C. are comparatively the least influenced if not entirely suppressed as is the case for pure austenitic steel. On the contrary, the temperature of the disintegration of austenite is increased considerably both by addition of chromium and of manganese. In this case, the second reduction in length can be separated into two parts, of which one lies, as usual at 280° C., the other connects with the increase in length connected with the disintegration of austenite. The action of the alloying additions is especially important particularly because they noticeably reduce the disintegration velocity of the hardening structure. The author supplements the measurements of length by a hardness test and an investigation of the structure. The explanation for the increase of hardness at 80° C. given by the author would, however, be better replaced by the one which sees here a refining phenomenon analogous to duraluminum. Regarding the many individual observations important for the explanations of phenomena in steel during hardening and tempering, they must be looked up in the paper itself.—G. Neuendorff.

Causeries sur les Fillons Metalliques. Paul Audibert. Dunod, Paris, 1929. Paper, 7 x 10 in., 240 pages, 33 figs.

The author of this book, a young mine manager, has had the thought of writing the results of his experience with various difficulties, for the benefit of other young mining engineers. This book is a supplement to the ordinary texts on mining. He discusses from a practical point of view, the characteristics of veins of ore, methods of draining and working, machinery, crushing, flotation, etc. The management of labor, mine organization, welfare work and similar topics are touched upon.—Frances M. Turner, Jr.

Blast Furnace Practice. By Fred Clements. Earnest Benn, Ltd., London, 1929. 538 pages, 375 figs. Price, 63 s.

Vol. 1. General Principles; Source, Preparation and Handling of Raw Materials.

After a short historical introduction, an introduction into the vast and complex subject of the present blast furnace practice and all the questions connected therewith is given. This is followed by the presentation of the properties of pig iron. The author then considers the theoretical basic principles, separated according to the chemical, thermal and physical principles. The next chapters are devoted to the raw materials: ores, additions, coke and air. The ore deposits, their geological character and their geographical distribution on the surface of the earth, as well as their economic value for the blast furnaceman are handled in great detail. After devoting a chapter each to the mining of the ores and the preparation of the ores for smelting, he discusses the additions, the metallurgical slag, the scrap and its influence on the operation of the furnace. He then devotes a chapter to the coke, its manufacture and properties, another chapter to the blast and its functions and concludes the book with a description of the transportation of the ores from the mines to the stockhouse.

The object of the author, to give a comprehensive work of the present day status of blast furnace practice was not wholly successful, in so far as the subjects covered in this volume are concerned. It would have been more valuable to the blast furnaceman to have omitted the chapters on geology, preparation of the ores for smelting and the production of coke and treated the chemical and thermal principles in more detail.

In spite of this, the book is very enlightening and should prove a valuable addition to the metallurgical literature. It is profusely illustrated with photographs, maps, plans, diagrams, tables and working schedules.—Richard Rimbach.

Zugfestigkeit und Härte Bei Metallen. Otto Schwarz. V. D. I. Verlag, Berlin, 1929. (Forschungsarbeiten, Heft 313), 8 x 11 inches, 34 pages, 6 R. M.

With the growing use of non-ferrous metals and the very general use of the Brinell test for semi-finished and finished materials, a clear understanding of the theoretical and practical relations between tensile strength and hardness becomes very important. These relations are very carefully studied in this treatise. The author first investigates the question theoretically and derives laws showing the relationship. He then describes his investigations in detail and gives the experimental results obtained with brass, nickel, aluminum, duralumin and Skleron. Tables, based on these results, giving the factors for converting hardness to tensile strength are given. Relation of hardness to strength for copper and steel at higher temperatures and for cast metals is also shown.—Richard Rimbach.

Messung Mechanischer Schwingungen. By Hermann Steuding. V. D. I. Verlag, Berlin, Germany, 1928. Cloth, 6 × 8, 500 pages. Price, 28 R. M.

This book obtained the prize offered in 1925 by the Verein Deutscher Ingenieure for the best critical investigation of methods and apparatus for measuring mechanical vibration. It is a convenient and thorough review both of the literature on the subject and of the methods and apparatus in practical use.

After an interesting classification of methods and apparatus from the viewpoints of physical principles and applications, the author first considers seismometry. The general theory of apparatus for measuring vibration is then discussed and criteria established for judging it. In the following chapters the individual methods, arranged by their uses, are reviewed. The fields considered are biology and physiology, varying stresses in structures and machines, acoustics, periodic vibrations in machinery and indicators for engines. A valuable bibliography of over fourteen hundred references is included.—G. Neuendorff.

Patent Department

Through an arrangement with Mr. W. M. Corse, Metallurgical Engineer, Washington, D. C., who operates a well-known Patent Information Service, we are able to publish every month a list of important patents in the metallurgical field from the United States, Canada and Europe. The following countries will be included in the European listing: England, Germany, France, Switzerland, Denmark, Norway, Sweden and Italy.

If our readers wish more information about any of the patents listed below they can get it by writing to our Patent Department, and mentioning the fact that they have seen the reference in METALS & ALLOYS. *We will be prepared to mail copies of United States Patents to clients within twenty-four hours of date of issue by special arrangement. Photostatic copies, translations of claims and of full text of foreign patents will be supplied if desired.*

This service is furnished under special arrangement with Mr. Corse's organization at most reasonable rates. Full information can be secured by writing to Patent Department, METALS & ALLOYS, *419 Fourth Avenue, New York.*

United States Patents

Patents issued from July 16 to August 13, inclusive

Patent No. — Patentee, Subject of Invention, and Filing Date

1,720,662 T. F. Burke, Brooklyn, N. Y. *Electric welding.* Jan. 20, 1926.

1,720,664 A. Churchward, New York, N. Y., assignor to Wilson Welder & Metals Co., Inc., Hoboken, N. J. *Electric welding apparatus.* Nov. 8, 1926.

1,720,675 G. L. Hertz, Eindhoven, Netherlands, assignor to N. V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands. *Manufacture of oxide cathodes.* July 25, 1924, in the Netherlands, Feb. 18, 1924.

1,720,668 G. B. Pickop, New Haven, Conn. *Sand riddle.* June 25, 1921.

1,720.722 R. S. Dean, Riverside, Ill., assignor to Western Electric Co., Inc., New York, N. Y. *Slug for use in extrusion operations and method of extrusion.* Nov. 26, 1927.

1,720,741 W. H. Millspaugh, Sandusky, Ohio, assignor to The Paper & Textile Machinery Co., Sandusky, Ohio. *Mold-forming apparatus.* Jan. 13, 1928.

1,720,815 V. Bendix, Chicago, Ill., assignor to Bendix Brake Co., South Bend, Ind. *Brake drum (with cemented surface).* May 2, 1928.

1,720,853 R. J. Norton, Washington, D. C., assignor to Bendix Brake Co., South Bend, Ind. *Brake apparatus (brake drum with alloy surface).* May 2, 1928.

1,720,857 J. E. Perry, Sharon, Pa., assignor to Valley Mould & Iron Corp, Sharpsville, Pa. *Steel ingot.* Mar. 18, 1927, division or application filed Jan. 18, 1926.

1,720,861 A. H. Stebbins, Los Angeles, Calif. *Classifier.* Oct. 14, 1926.

1,720,862 A. H. Stebbins, Los Angeles, Calif. *Table concentrator.* June 3, 1927.

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1,721,038 R. Reinert, La Chaux-de-Fonds, Switzerland. *Process for the manufacture of metallic diaphragms for talking machines, telephone and wireless apparatus, etc.* June 23, 1927, in Germany June 26, 1926.

1,721,042 B. L. Rowe, Barstow, Calif. *Machine for upsetting drawbars.* Mar. 21, 1927.

1,721,063 R. J. Barnes, Philadelphia, Pa. *Flask-filling machine for use in foundries.* Sept. 11, 1925.

1,721,073 W. Esmarch, Berlin-Halensee, Germany, assignor to Siemens & Halske Akt.-Ges., Berlin-Siemensstadt, Germany. *High-frequency induction furnace.* Oct. 12, 1927, in Germany June 10, 1927.

1,721,088 W. H. Ramage, Girard, Ohio, assignor to Valley Mould & Iron Corp., Sharpsville, Pa. *Hot top with integral-brick lining.* May 11, 1927.

1,721,092 C. M. Saeger, Jr., Washington, D. C. *Metal-spraying device.* May 8, 1925.

1,721,115 W. A. Harrington, Leichhardt, near Sydney, New South Wales, Australia. *Centrifugal casting apparatus for molding metal and other materials.* Feb. 1, 1928, in Australia Feb. 24, 1927.

1,721,169 K. M. van Gessel, Eindhoven, Netherlands, assignor to Radio Corporation of America. *Manufacture of oxide cathodes.* Apr. 6, 1927, in the Netherlands Apr. 6, 1926.

1,721,184 C. F. Mead, Cleveland, Ohio. *Wire-drawing mechanism.* Mar. 26, 1925.

1,721,265 N. T. Wellman, Ridley Park, Pa., assignor to General Chemical Co., New York, N. Y. *Roasting furnace.* June 25, 1925.

1,721,283 F. M. Ruth, Sterling, Ill., assignor to Russell, Burdsall & Ward Bolt & Nut Co., Port Chester, N. Y. *Swaging machine.* July 30, 1927.

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Patent No. — Patentee, Subject of Invention, and Filing Date

1,721,357 R. W. Siler, Long Beach, Calif. *Method of treating metallic bodies (with liquid air).* May 25, 1928.

1,721,373 H. E. Coley, London, England. *Process for the manufacture of Zinc.* Aug. 8, 1927, in Great Britain Feb. 2, 1927.

1,721,379 W. Ehlers, Copenick, and F. Falkenberg, Berlin, Germany, assignors to General Electric Co. *Magnetic core and method of manufacture.* July 9, 1926, in Germany July 25, 1925.

1,721,383 G. R. Fonda, Schenectady, N. Y., assignor to General Electric Co. *Metal composition (tungsten, thorium oxide, and boron nitride).* May 1, 1923.

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1,721,414 W. B. Robe, Towson, Md., assignor to Rekeen Tool Co., Inc., Baltimore, Md. *Process and apparatus for recutting or sharpening all tools having numerous fine cutting edges.* Aug. 2, 1927.

1,721,416 K. Schröter, Berlin-Lichtenberg, Germany, assignor to General Electric Co. *Hard-metal composition.* Apr. 26, 1926, in Germany May 7, 1925.

1,721,475 H. Skall, Chicago, Ill., assignor to Danly Machine Specialties Inc., Chicago, Ill. *Work-rest blade for centerless grinders (made of a chilled ferrous alloy).* Feb. 6, 1928.

1,721,490 W. H. Ramage, Girard, Ohio, assignor to Valley Mould & Iron Corp., Sharpsville, Pa. *Ingot mold.* Jan. 28, 1926.

1,721,548 J. H. Deppeler, Weehawken, N. J. *Method of welding railway rails and the like.* Jan. 28, 1928.

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1,721,569 J. D. McCutcheon, Pittsburgh, Pa. *Cutting Torch.* Nov. 11, 1927.

1,721,594 H. Hardinge, York, Pa., assignor to Hardinge Co., Inc., York, Pa, *Classification system for pulverized materials.* Dec. 31, 1927. division of application filed Aug. 28, 1925.

1,721,687 W. Brinton, Wilmington, Del., assignor to American Manganese Steel Co., Chicago, Ill. *Mold for casting rail crossings.* Apr. 23, 1925.

1,721,688 W. Brinton, Wilmington, Del., assignor to American Manganese Steel Co., Chicago, Ill. *Chill for casting railway crossings.* Nov. 5, 1927.

1,721,695 G. H. Hufferd and M. P. Graham, Detroit, Mich, assignors to Thompson Products Inc., Cleveland, Ohio. *Method of making tubular front axles.* Dec. 19, 1925.

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1,721,814 K. Geisel, Levallois-Perret, France, assignor by mesne assignments to Aluminum Solder Corporation of America, New York, N. Y. *Soldering composition.* Sept. 21, 1928.

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1,721,966 O. L. Mills, Los Angeles, Calif. *Process for making tungsten alloys.* Jan. 11, 1929.

1,721,969 W. H. Nichols, Wilkinsburg, Pa. *Apparatus for casting chill rolls and the like.* Dec. 17, 1928.

1,721,993 W. F. Green, Bauer, Utah, assignor to Combined Metals Reduction Co., Bauer, Utah. *Separation of mixed sulfide ores by flotation.* July 2, 1925.

1,721,994 G. R. Greenslade, Pittsburgh, Pa., F. K. Landgraf, Grafton, Pa., and J. R. Flannery, Pittsburgh, Pa., assignors to Flannery Bolt Co., Pittsburgh, Pa. *Pot (made of heat- and corrosion-resistant metals).* Mar. 14, 1928.

1,722,001 C. W. Kinter, Follansbee, W. Va. *Pickling apparatus.* Mar. 5, 1928.

1,722,025 H. Wagener, Berlin-Wilmersdorf, Germany. *Process for brazing copper alloys to iron alloys.* Oct. 16, 1926, in Great Britain Dec. 24, 1925.

1,722,040 C. Dursch, Nuremberg, Germany. *Welding and soldering composition.* Sept. 6, 1928, in Germany Sept. 10, 1927.

1,722,079 G. W. Elmen, Leonia, N. J., assignor to Western Electric Co., Inc., New York, N. Y. *Heat treating metallic conductors.* Nov. 20, 1922.

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1,722,124	C. Adey and C. Piel, Solingen, Germany. *Method of casting copper alloys.* May 19, 1924, in Germany May 22, 1923.
1,722,195	W. D. Bumstead, Cleveland, and E. A. Aurada, Cleveland Heights, Ohio, assignors to General Electric Co. *Method of electric-welding wires.* Apr. 23, 1928.
1,722,251	P. G. Palmgren, Gottenborg, Sweden, assignor to Aktiebolaget Svenska Kullagerfabriken, Gottenborg, Sweden. *Coupling box for rolling mills.* Apr. 8, 1927, in Sweden Apr. 13, 1926.
1,722,263	R. K. Barry and L. Bowen, Muscatine, Iowa. *Hardness-testing machine.* Sept. 10, 1924.
1,722,281	W. J. During, Syracuse, N. Y., assignor to Precision Castings Co., Inc., Fayetteville, N. Y. *Die casting and method of producing same.* Nov. 17, 1925.
1,722,354	G. A. Reinhardt, Youngstown, Ohio. *Mold for centrifugal castings* Feb. 28, 1925.
1,722,358	K. S. Seljesaeter, Chicago, Ill., assignor to Western Electric Co., Inc., New York, N. Y. *Alloy and method of making alloys (Pb-Sb-As).* July 6, 1927.
1,722,371	F. L. Feltes, Cleveland, Ohio, assignor by mesne assignments to Aluminum Company of America, Pittsburgh, Pa. *Piston-casting machine.* Feb. 12, 1926.
1,722,372	C. A. Hallam, La Grange, Ill., assignor to Western Electric Co., Inc., New York, N. Y. *Method of reclaiming metal portions of electrical apparatus.* Mar. 26, 1926.
1,722,380	F. S. Kochendorfer, River Forest, and W. N. Those, Chicago, Ill. assignors to Western Electric Co., Inc., New York, N. Y. *Mold-handling mechanism.* Feb. 8, 1926.
1,722,414	F. L. Feltes, Cleveland, Ohio, assignor by mesne assignments to Aluminum Company of America, Pittsburgh, Pa. *Molding machine.* Dec. 13, 1926.
1,722,418	C. C. Grotnes, Chicago, Ill. *Metal-working machine (uses forming rolls).* Aug. 4, 1928.
1,722,421	W. F. Hosfors, Oak Park, Ill., assignor to Western Electric Co., Inc., New York, N. Y. *Wire-drawing machine.* June 6, 1922.
1,722,449	G. E. Barnhart. *Heat-treating-furnace organization for metallic units.* Nov. 26, 1926.
1,722,528	R. Luckenbach, Brooklyn, N. Y. *Flotation oil.* Mar. 23, 1925.
1,722,598	J. L. Stevens, Hayden, Ariz. *Concentration of ores.* Mar. 26, 1928.
1,722,634	G. R. Kinkead, New York, N. Y. *Apparatus for making hollow articles by extrusion.* Oct. 23, 1928.
1,722,701	G. H. Isley, Worcester, Mass., assignor to Morgan Construction Co., Worcester, Mass. *Apparatus for reversing and controlling regenerative furnaces.* Jan. 23, 1925.
1,722,705	S. E. Meyer, Hayden, Ariz. *Flotation machine.* Apr. 20, 1927.
1,722,711	F. L. Sessions, Lakewood, Ohio, assignor to Steel and Tubes, Inc., Cleveland, Ohio. *Tube-welding machine.* Sept. 27, 1922.
1,722,777	H. G. Wellman, East Cleveland, Ohio. *Crucible-handling device.* Jan. 12, 1927.
1,722,929	J. C. Lincoln, East Cleveland, Ohio, assignor to The Citizens Savings and Trust Co., Cleveland, Ohio. *Flux holder (for welding operations).* Jan. 29, 1920, renewed June 8, 1928.
1,722,949	E. R. Wehr and C. C. Mahlie, Middletown, Ohio, and J. R. Cain, Washington, D. C., assignors to American Rolling Mill Co., Middletown, Ohio. *Metal coating metal sheets.* June 1, 1926.
1,722,995	F. W. Burger and B. Stockfleth, Niles, Mich., assignors to Hydraulic Pressed Bearing Co., Wilmington, Del. *Die mechanism and extrusion method of forming metal articles.* Mar. 10, 1924.
1,723,006	R. A. Bennett, Denver, Colo. *Ore-roasting retort furnace.* Mar. 5, 1928.
1,723,015	H. A. De Fries, Albany, N. Y., assignor to Ludlum Steel Co., Watervliet, N. Y. *Molybdenum nitriding steels and process of nitriding same.* Mar. 2, 1928.
1,723,067	A. Pacz, East Cleveland, Ohio. *Method and composition of matter for coating and coloring metal articles.* Apr. 16, 1926.
1,723,071	P. A. Pitman, Quincy, Mass. *Apparatus for making small castings.* Aug. 6, 1926.
1,723,098	F. Ungerer, Pforzheim, Germany. *Method and apparatus for straightening plates.* June 13, 1928. in Germany May 31, 1927.
1,723,106	E. Wiglenda, Spandau, Germany, assignor to Rohrbach Metall-Flugzeugbau G. m. b. H., Berlin, Germany. *Device for cutting out plate work pieces.* Feb. 4, 1927, in Germany Jan. 9, 1926.
1,723,109	F. J. Winder, Brackenridge, Pa., assignor to The Surface Combustion Co., Inc., New York, N. Y. *Normalizing furnace.* Oct. 7, 1927.
1,723,152	H. T. Grafton, Bristolville, Ohio. *Production of ductile iron and steel sheets.* Feb. 10, 1928.
1,723,315	W. S. Smith, Newton Poppleford, and H. J. Garnett, Sevenoaks, England. *Manufacture of wires and tapes for loading telephone conductors.* Feb. 17, 1926, in Great Britain Feb. 17, 1925.
1,723,243	C. P. Lewis, Burlingame, Calif., assignor to Minerals Separation North American Corp., New York, N. Y. *Froth-flotation concentration of ores.* Aug. 4, 1926, in Great Britain Aug. 12, 1925.
1,723,277	D. Gray and R. O. Bailey, Oneida, and W. S. Murray, Utica, N. Y., assignors to Oneida Community, Ltd., Oneida, N. Y. *Aluminum-plated article and process for producing the same.* Apr. 5, 1924, renewed Oct. 26, 1928.
1,723,295	A. H. Nye, New York, N. Y. *Process for flotation of ores.* May 2, 1927.
1,723,316	P. V. Tippet, Cuyahoga Falls, Ohio, assignor to The Vaughn Machinery Co. Cuyahoga Falls, Ohio. *Wire-drawing mechanism.* Apr. 9, 1924.
1,723,310	E. Wirz, Baden, Switzerland, assignor to Akt.-Ges. Brown, Boveri & Cie., Baden, Switzerland. *Heating-furnace apparatus (for heat treating).* Feb. 18, 1926, in Germany Feb. 24, 1925.
1,723,345	W. J. Green, Pittsburgh, Pa. *Mold for casting bimetal products.* Nov. 8, 1926.
1,723,411	A. Dossmann, Genoa, Italy. *Process for the treatment of scrap iron* Aug. 4, 1927, in Italy June 10, 1927.
1,723,444	J. Savelsberg, Papenburg-on-the-Ems, Germany, assignor C. Schlesinger & Trier Kommanditgesellschaft auf Aktien, Berlin, Germany. *Method of producing metals (recovery of Pt from ores).* Oct. 28, 1927, in Germany Nov. 29, 1926.
1,723,480	A. H. Hannon, Chicago, Ill. *Electroplating machine.* Mar. 31, 1927.
1,723,538	J. E. Batie, Detroit, Mich., assignor to Kelsey Wheel Co., Inc., Detroit, Mich. *Heating apparatus.* May 16, 1927.
1,723,582	M. O. Sem, Oslo, Norway, assignor to Det Norske Aktieselskab for Elektrokemisk Industri of Norway, Oslo, Norway. *Electrode for electric furnaces.* Apr. 7, 1927, in Norway Apr. 7, 1926.
1,723,595	W. Alderdice, Brooklyn, N. Y., assignor to Alfred W. Channing, Inc., New York, N. Y. *Metal feeder (for feeding metal bars to melting pot).* Sept. 17, 1926.
1,723,601	A. W. Corroll, Elizabeth, N. J. *Apparatus for casting metal ingots* Jan. 23, 1928.
1,723,711	V. P. Roes, Clarkston, Wash. *Concentrator.* Oct. 22, 1927.
1,723,712	S. E. Sperry, Hollis, N. Y., assignor to Intertype Corp., Brooklyn, N. Y. *Mold for line-casting machines.* May 22, 1928.
1,723,760	F. M. Bowers, Chester, Pa. *Electrode holder (for welding electrodes).* Oct. 17, 1927.
1,723,769	A. L. Davis, Waterbury, Conn., assignor to Scovill Manufacturing Co., Waterbury, Conn. *Method of producing headed metal articles.* Nov. 18, 1925.
1,723,773	A. L. Eicher, Canal Fulton, Ohio. *Forged worm gear.* Nov. 5, 1926., division of application filed June 26, 1926.
1,723,792	J. B. Ladd, Ardmore, Pa., assignor to United States Cast Iron Pipe and Foundry Co., Burlington, N. J. *Machine for drawing pipes from molds.* Jan. 19, 1928.
1,723,795	M. J. Lide, Birmingham, Ala. *Concentrating table.* Mar. 10, 1926.
1,723,862	R. Jacoby, Berlin, Germany, assignor by mesne assignments to General Electric Co., Schenectady, N. Y. *Process for the manufacture of drawn tungsten wires.* June 16, 1921, in Germany May 7, 1920.
1,723,867	M. G. Korsunsky (now M. G. Corson), Jackson, Heights, N. Y., assignor to Electro Metallurgical Co. *Alloy for electrical conductors (Cu-Cr).* Dec. 9, 1924.
1,723,868	F. C. Langenberg, Watertown, Mass. *Alloy steel (Fe-Mn-Mo-Zr)* Jan. 24, 1927.
1,723,922	M. G. Corson, Jackson Heights, N. Y., assignor to Electro Metallurgical Co. *Copper-cobalt alloy.* Apr. 13, 1926.
1,723,923	J. G. Davidson, Yonkers, N. Y., assignor to Carbide & Chemicals Corp. *Inhibitor (for pickling baths).* Mar. 14, 1928.
1,723,928	H. A. Fisher, Worcester, Mass. *Rolling-mill bearing.* Sept. 1, 1925.
1,723,982	W. R. Pate and J. A. Gitzen, Milwaukee, Wis., assignors to Lindsay-McMillan Co., Milwaukee, Wis. *Liquid core binder.* Apr. 11, 1927.
1,723,984	E. J. von Henke, Chicago, Ill., assignor to American Electric Fusion Corp., Chicago, Ill. *Electric welding machine.* Oct. 6, 1927, division of application filed Sept. 11, 1926.
1,724,031	G. Langford, Joliet, Ill., assignor to McKenna Process Company of Illinois, Joliet, Ill. *Method of heat-treating metal bars.* Apr. 27, 1927.
1,724,058	S. G. Worton, Duquesne, Pa. *Soaking-pit furnace.* Feb. 2, 1928.
1,724,070	L. Byrne and G. P. Lowell, Chicago, Ill. *Soldering iron.* Dec. 5, 1928.
1,724,098	J. D. MacKenzie and R. W. Senger, Garfield, Utah, assignors to American Smelting and Refining Co., New York, N. Y. *Furnace-roof construction.* Apr. 2, 1927.
1,724,100	T. G. Martyn, deceased, Fordsburg, Johannesburg, South Africa, by G. E. Martyn, executrix, Fordsburg, Johannesburg, South Africa. *Sorting pulp.* Dec. 24, 1926, in South Africa, Jan. 7, 1926.
1,724,134	C. V. Iredell, Bloomfield, N. J., assignor to Westinghouse Lamp Co. *Lubricant for wire-drawing.* Sept. 29, 1926.
1,724,196	B. S. Harrison, Cleveland, Ohio. *Core drier.* Sept. 26, 1927.
1,724,280	E. J. Gulick, Elkhart, Ind. *Method for the manufacture of musical instrument bells.* Feb. 17, 1928.
1,724,282	J. H. Hoern, Saginaw, Mich., assignor to Wilcox-Rich Corp., Detroit, Mich. *Making poppet valves.* Feb. 13, 1928.
1,724,299	W. M. Mitchell, Philadelphia, Pa., assignor by mesne assignments to Electro Metallurgical Co. *Casting having chromium alloy surface.* Sept. 24, 1924.
1,724,304	W. E. Newnam, Collinsville, Ill., assignor to National Lead Co., St. Louis, Mo. *Pig-lead stacking machine.* July 30, 1923, renewed Dec. 21, 1927.
1,724,314	E. Röber, Düsseldorf, Germany. *Rolling mill of the pilger type.* June 29, 1926, in Germany Nov. 25, 1925.
1,724,323	H. G. Stoddard, Worcester, Mass., assignor to Wyman-Gordon Co., Worcester, Mass. *Method of preparing steel billets for forging.* Dec. 21, 1927.
1,724,331	W. O. Will and E. Carlson, Chicago, Ill., assignors to Stewart Die Casting Corp., Chicago, Ill. *Die-casting machine.* June 29, 1927.
1,724,332	W. O. Will and E. Carlson, Chicago, Ill., assignors to Stewart Die Casting Corp., Chicago, Ill. *Hydraulically-operated die-casting machine.* Aug. 25, 1927.
1,724,340	H. L. Charles, Kent, Wash. *Smelting furnace.* Nov. 27, 1926 division of application filed Dec. 29, 1925.
1,724,381	E. J. von Henke, Chicago, Ill., assignor to American Electric Fusion Corp., Chicago, Ill. *Welding machine.* Nov. 6, 1926.
1,724,395	D. J. Conant, Memphis, Tenn., assignor to Westinghouse Electric & Manufacturing Co. *Die-casting machine.* Aug. 3, 1927.
1,724,436	E. J. Sweetland, Hazleton, Pa., assignor to Oliver United Filters, Inc., San Francisco, Calif. *Thickener.* Jan. 24, 1924.
1,724,455	J. W. Cox, Erie, Pa. *Furnace.* Dec. 12, 1924.
1,724,490	C. H. Mace, Denver, Colo. *Smelting furnace.* Jan. 30, 1925.
1,724,552	A. E. Bellis, Branford, Conn., *Salt bath.* Sept. 10, 1925.
1,724,552	A. E. Bellis, Branford, Conn., *Salt bath.* Mar. 18, 1929, division of application filed. Sept. 10, 1925.
1,724,583	C. I. Hayes, Providence, R. I. *Electric furnace (for heat treating)* May 12, 1928.
1,724,624	E. Strasser, Rorschach, Switzerland, assignor to M. Dietiker, Zürich, Switzerland. *Process for the production of aluminum castings and molds for use therein.* Dec. 7, 1925, in Germany Dec. 13, 1924.

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1,724,656	G. H. Isley, Worcester, Mass., assignor to Morgan Construction Co., Worcester, Mass. *Operation and construction of regenerative furnaces used in steel making.* Jan. 17, 1927.
1,724,680	P. C. Ripley, Chicago, Ill., assignor to Kester Solder Co., Chicago, Ill. *Rosin-core solder.* Feb. 4, 1927.
1,724,794	W. W. Davis, Great Neck, N. Y. *Method of detecting ore deposits.* Feb. 20, 1925.
1,724,818	A. E. Averrett, Schenectady, N. Y., assignor to General Electric Co. *Brazing alloy.* June 12, 1928.
1,724,848	F. R. McGee, Steubenville, Ohio. *Hot-blast stove.* Nov. 2, 1927.
1,724,849	G. M. Mowl, Monessen, Pa., assignor to American Sheet and Tin Plate Co., Pittsburgh, Pa. *Pack-opening machine.* Jan. 15, 1926.
1,724,867	L. B. Andresen, Minneapolis, Minn., assignor to M. F. Patterson Dental Supply Co., St. Paul, Minn. *Heating device.* July 25, 1927.
1,724,886	K. E. Peiler, West Hartford, Conn., assignor to Hartford-Empire Co., Hartford, Conn. *Manufacture of refractory compositions.* June 1, 1925.

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Re 17,385	P. Berthélemy and H. De Montby, Paris, France. *Aluminum alloy and method of manufacturing the same.* Sept. 15, 1927. (Original 1,599,869, dated Sept. 14, 1926, filed June 16, 1925, in France May 11, 1925.)
Re 17,388	F. T. Cope and R. F. Benzinger, Salem, Ohio, assignors to The Electric Furnace Co., Salem, Ohio. *Electric furnace.* Aug. 20, 1928. (Original No. 1,647,726, dated Nov. 1, 1927, filed Mar. 6, 1926.)

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113,973	Gesellschaft für Elektrodenzerstäubung m. b. H., Böhlitz-Ehrenberg, near Leipzig, Germany. *Process for metallizing organic materials.* Mar. 15, 1929.
113,977	Aluminium Industrie Akt.-Ges., Neuhausen, Switzerland. *Process for the electrolytic recovery of pure aluminum from crude aluminum.* Mar. 15, 1929.
113,982	Società Italiana Ernest Breda, Milan, Italy. *Electrometallurgical melting and refining furnace.* Mar. 15, 1929.
114,055	Établissements Alph. Binet, Soc. An., Paris, France. *Device for casting bearings, connecting-rod ends, and the like.* Mar. 15, 1929.
114,147	G. Martin, Wembley, England. *Shaft furnace for roasting, calcining and sintering pulverized raw materials.* Mar. 15, 1929.

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Patent No.	Patentee, Subject of Invention, and Filing Date
313,930	J. Euteneuer, A. Abrams, and F. Hoffmann. *Automatic conveying devices, particularly for rolling mills.* June 19, 1928.
313,973	I. G. Farbenindustrie Akt.-Ges. *Manufacture of metallized sheets.* June 20, 1928.
314,032	Climax Molybdenum Co. *Ferrous molybdenum alloys.* Nov. 1, 1927.
314,044	Ingersoll-Rand Co. *Forging machine.* June 22, 1928.
314,056	Vereinigte Stahlwerke Akt.-Ges. *Heat-treatment for hardened Steel.* June 22, 1928.
314,063	Svenska Aktiebolaget Gas-accumulator. *Welding machines.* June 22, 1928.
314,066	Russell, Burdsall & Ward Bolt & Nut Co. *Method of and apparatus for making nut blanks.* June 23, 1928.
314,084	International General Electric Co., Inc. *Methods of manufacturing sheet-metal packets such as magnetic groove wedges.* June 22, 1928.
314,370	E. Kamp. *Process for the production of forged shafting.* June 26, 1928.
314,378	H. D. Scott. *Packaging of tin plate.* June 26, 1928.
314,387	Mannesmannröhren Werke. *Rolling mills.* June 26, 1928.
314,392	Siemens & Halske Akt.-Ges. *Method of and means for sectional electroplating, particularly applicable for plating large objects with chromium.* June 26, 1928.
314,423	Electro Metallurgical Co. *Process of case-hardening by nitrification.* June 27, 1928.
314,434	E. Kelsen. *Process of and apparatus for producing metal sheets by electrolytic means.* June 27, 1928.
314,439	Siemens & Halske Akt.-Ges. *Decarburizing of iron and steel and their alloys.* June 27, 1928.
314,444	E. Kelsen. *Process and apparatus for electrolytically manufacturing metal sheets and tubes.* June 27, 1928.
314,522	Standard Telephones & Cables, Ltd. *Lead alloy electric cable sheaths.* June 29, 1928.
314,523	Babcox & Wilcox Tube Co. *Methods of an apparatus for making seamless tubes.* June 30, 1928.
314,878	W. Erfurth. *Process for drawing zinc shells.* July 3, 1928.
314,944	De Bataafsche Petroleum Maaschappij. *Process for manufacturing nickel in a finely divided state, in particular for the catalytic manufacture of hydrogen.* July 5, 1928.
314,971	British Thomson-Houston Co. *Magnetic alloys and methods of making the same.* July 6, 1928.
315,301	Geb. Lüngen Ges. *Production of steel castings.* July 11, 1928.
315,343	M. U. Schoop. *Method and a device for producing homogeneous metallic coatings and particularly lead coatings.* July 12, 1928.
315,394	Molybdenum Corporation of America. *Ferrous-base article and method of making same.* July 13, 1928.
315,724	British Thomson-Houston Co. *Methods of making malleable iron.* July 16, 1928.
315,758	Metallic Shaft Co. *Metallic tubes or shafts and process of producing the same.* July 17, 1928.
315,760	Davis Steel Process Corp. *Process of reducing iron ores.* July 17, 1928.
315,826	A. M. Byers Co. *Methods of making wrought iron.* July 19, 1928.
315,827	A. M. Byers Co. *Methods of making wrought iron.* July 19, 1928.
315,828	A. M. Byers Co. *Methods of making wrought iron.* July 19, 1928.
315,829	A. M. Byers Co. *Methods of making wrought iron.* July 19, 1928.
315,856	Hartford-Empire Co. *Manufacture of refractory articles.* July 21, 1928.
315,858	A. M. Byers Co. *Methods of preparing molten slag, particularly for wrought iron use.* July 21, 1928.
316,098	Schiess-Defries Akt.-Ges. *Forging machines.* July 21, 1928.
316,103	Bayerische Metallwerke Akt.-Ges. *Method of manufacturing hydrocarbon-containing metals and alloys.* July 20, 1928.

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287,556	Laboratoire de Perfectionnements Thermiques. *Walls, furnaces and installations formed of refractory materials resistant to destructive effects, and method and means for their production.* Mar. 24, 1927.
287,911	J. H. Gravell. *Pickling of iron and steel.* Mar. 29, 1927.
288,160	British Thomson-Houston Co., Ltd. *Arc-welding systems.* Apr. 1, 1927.
288,333	British Thomson-Houston Co., Ltd. *Purification of alkali or alkaline-earth metals, and the production of alloys therefrom.* Apr. 6, 1927.
288,551	Soc. La Carbonisation Soc. Générale d'Exploitation des Carbones. *Process for the manufacture and use of metallurgical carbons.* Apr. 11, 1927.
288,973	I. G. Farbenindustrie Akt.-Ges. *Process for the refining of chromium ores.* Apr. 16, 1927.
290,182	Eisenwerk-Ges. Maximilian-Shütte. *Method of and apparatus for obtaining uniform hardness when hardening the head of railway rails.* May 5, 1927.
290,267	International Nickel Co. *Manufacture of cast iron.* May 13, 1927.
293,395	British Thomson-Houston Co., Ltd. *Electric immersion heaters, particularly for type-metal pots.* July 5, 1927.
294,176	Carborundum Co. *Manufacture of carbon electrodes and other refractory articles.* July 19, 1927.
296,082	Vereinigte Stahlwerke Akt.-Ges. *Process for the manufacture of metal rings, and especially of wheel tyres.* August 26, 1927.
296,086	Maschinenfabrik Augsburg-Nürnberg Akt.-Ges. *Method of heating melting pots for type, stereotype, and the like casting-machines.* Aug. 26, 1927.
297,813	A. Dawans. *Device for melting finely divided materials and process for agglomerating blast-furnace dust.* Sept. 30, 1927.
298,636	Metalges. Akt.-Ges. *Process for the production of zinc from oxidic zinc compounds.* Oct. 13, 1927.
299,298	J. Q. MacDonald and W. M. Scott. *Electroplating.* Oct. 22, 1927.
299,873	J. P. Kittredge. *Casting of metal wheels.* Nov. 3, 1927.
300,248	Barber Asphalt Co. *Metallic alloy.* Nov. 10, 1927.
300,250	Barber Asphalt Co. *Metallic alloy.* Nov. 10, 1927.
300,559	P. Marx. *Smelting furnaces.* Nov. 14, 1927.
301,739	P. Marx. *Smelting furnaces.* (Addition to 300,559). Dec. 3, 1927.
302,640	V. B. Browne. *Method of rendering iron-chromium-aluminum alloys ductile.* Dec. 19, 1927.
303,417	Vacuumschmelze Ges., and W. Rohn. *Process for the production and repair of refractory linings for hearths of metallurgical and other furnaces.* (Addition to 226,801). Jan. 2, 1928.
304,152	Hartstoff-Metal Akt.-Ges. (Hametag). *Pulverizing mill.* Jan. 14, 1928.
304,676	Soc. La Carbonisation Soc. Générale d'Exploitation des Carbones. *Process for the manufacture and use of metallurgical carbons.* (Addition to 288,551). Jan. 24, 1928.
305,569	Soc. Electrometallurgique de Montricher. *Poking and stirring apparatus for electric furnaces.* Feb. 7, 1928.
308,676	Siemens-Schuckertwerke Akt.-Ges. *Furnaces for annealing stampings.* Mar. 26, 1928.
313,583	Mannesmannröhren-Werke. *Method of and means for centrifugal casting of metal blocks.* June 15, 1928.
313,891	C. Müller. *Process of manufacturing thin bodies made from alloys of metal or metalloids.* Dec. 21, 1926.
313,901	Dr. O. Sprenger Patentverwertung Jirotka, and B. Jirotka. *Processes for producing coatings on metal articles.* (Addition to No. 249,971.) Mar. 19, 1928.
314,032	Climax Molybdenum Co. *Ferrous molybdenum alloys.* Dec. 29, 1927.
314,153	E. V. Simpson, and D. Sands (trading as Simpson & Sands). *Machines employed in the manufacture of nails.* Apr. 12, 1928.
314,164	W. Kenyon, and R. Wastnidge. *Manufacture of file, rasp and the like blanks by rolling processes.* Apr. 21, 1928.
314,171	Woodall-Duckham (1920), Ltd., and M. H. McEwan. *Regenerative furnaces.* Apr. 28, 1928.
314,176	H. E. Potts (communicated by Electro Metallurgical Co.). *Wrought articles of iron-chromium-nickel alloy.* (Addition to No. 297,045). May 7, 1928.
314,219	R. Esnault-Pelterie. *Treatment of iron and steel.* June 26, 1928.
314,225	T. Morgan, and R. H. Morgan & Co., Ltd. *Packing of tinplates or the like.* July 6, 1928.
314,271	K. Lohs. *Process for the hot pressing of wheel bosses and similar parts from a block blank.* Sept. 1, 1928.
314,280	J. F. Boyer. *Brazing, sweating or soldering devices or appliances for use in soldering the joints of metal tubes or the like.* Sept. 19, 1928.

Patent No.	Patentee, Subject of Invention, and Filing Date
314,314	J. Y. Johnson (communicated by I. G. Farbenindustrie Akt.-Ges.). *Process for producing non-corrosive and heat-resisting surfaces on iron.* Mar. 19, 1928.
314,470	Electro Bleach & By-Products, Ltd., and J Hollins. *Electrodeposition of metals.* Feb. 25, 1928.
314,558	Electro Bleach & By-Products, Ltd., and J. Hollins. *Electrodeposition of metals.* Feb. 25, 1928.
314,579	S. C. Smith. *Electrolytic recovery of metals.* Mar. 30, 1928.
314,585	A. Carlson. *Method of and means for increasing the output of mechanical roasting furnaces and the like.* Mar. 31, 1928.
314,594	I. Ainstein. *Electrodeposited protective coatings for vessels.* Feb. 4, 1928.
314,642	Perfecta Seamless Steel Tube & Conduit Co. (1923), Ltd., and H. Trevorrow. *Apparatus for the dipping of tubes or rods for pickling, cleaning, galvanizing and other purposes.* May 10, 1928.
314,667	International Nickel Co., W. J. Harshaw, P. M. Savage and F. K. Bezzenberger. *Manufacture of nickel anodes.* June 19, 1928.
314,728	Associated Electrical Industries, Ltd. (communicated by Westinghouse Electric & Manufacturing Co.). *Arc-welding apparatus.* Sept. 18, 1928.
314,769	Dr. O. Sprenger Patentverwertung Jirotka, and B. Jirotka. *Process for coating metals.* Mar. 2, 1928.
314,772	S. Travis, and Callow Rock Lime Co., Ltd. *Linings for furnaces, kilns and the like.* Mar. 27, 1928.
314,774	Birmingham Electric Furnaces, Ltd. and A. G. Lobley. *Current-supply control systems of electric furnaces and analogous electric heating installations.* Mar. 28, 1928.
314,775	Birmingham Electric Furnaces, Ltd., and A. G. Lobley. *Electric furnaces.* Mar. 28, 1928.
314,822	R. J. Lemmon. *Froth flotation.* Mar. 3, 1928.
314,912	Imperial Chemical Industries, Ltd., and B. P. Crawshaw. *Process and apparatus for degreasing metal and the like articles.* Feb. 4, 1928.
314,916	E. Hayward. *Apparatus for the continuous chemical, heat or other treatment of materials.* Mar. 5, 1928.
315,010	K. Geisel. *Fluxes for welding.* Mar. 8, 1928.
315,032	Burdons, Ltd., and W. H. Howden. *Oil-gas plant for welding purposes.* Apr. 26, 1928.
315,041	W. R. Hume. *Machines for bending metal plates or sheets.* May 7, 1928.
315,080	W. Nacken. *Multiple wire-drawing machines.* June 29, 1928.
315,088	J. Roux. *Rolling mills.* June 28, 1928.
315,120	E. S. Hume. *Apparatus for the manufacture or lining of pipes by centrifugal action.* Aug. 7, 1928.
315,246	Wild-Barfield Electric Furnaces, Ltd., and L. W. Wild. *Electric furnaces.* Apr. 10, 1928.
315,444	L. F. Reinartz, and J. H. Nead. *Process of making commercially pure iron alloys.* Feb. 14, 1928.
315,446	J. J. V. Armstrong (communicated by Badeschin Maschinenfabrik & Eisengiesserei). *Cleaning of metal castings.* Mar. 12, 1928.
315,459	H. Wade (communicated by Soc. Italiana per le Industrie Minerarie e Chimiche). *Process of and means for treating metallic oxides or other compounds with hydrocarbons.* Apr. 13, 1928.
315,460	J. Y. Johnson (communicated by I. G. Farbenindustrie Akt-Ges.). *Process for producing resistant silver surfaces.* Apr. 13, 1928.
315,481	F. Collingridge. *Apparatus for the recovery of metals by electrolysis.* Apr. 18, 1928.
315,502	L. Kluger, and Oesterreichische Schmidtstahlwerke Akt.-Ges. *Iron alloy for milling tools.* Apr. 27, 1928.
315,503	L. Kluger, and Oesterreichische Schmidtstahlwerke Akt.-Ges. *Heat-resisting alloys.* Apr. 27, 1928.
315,510	A. Lumb, and L. Lumb. *Apparatus for automatically indicating and recording the percentage of carbon dioxide contained in the combustion gases of furnace flues and the like.* May 7, 1928.
315,531	Kolloidchemie Studienges., J. B. Carpzow, M. March, R. Lenzmann and H. Sanders. *Method of deoxidizing oxidized metal surfaces, and of protecting metal surfaces against oxidation.* May 30, 1928.
315,673	H. Wade (communicated by International Nickel Co.). *Manufacture of alloy steel.* Feb. 2, 1928.
315,943	A. H. Marks, and P. Russell (communicated by Grasselli Chemical Co.). *Cadmium-plating.* May 12, 1928.
316,028	H. Möller. *Machine for drawing, cutting, straightening and polishing wire, rods and the like.* Aug. 13, 1928.

Canadian Patents

Canadian patents issued July 9 to August 6, inclusive.

Patent No.	Patentee, Subject of Invention, and Filing Date
291,091	G. De Dudzeele, Paris, France. *Treatment of tubes with lead.* Nov. 15, 1928.
291,099	Sir R. A. Hadfield, Westminster, England. *Manufacture of hollow metal rods, bars, etc.* Jan. 3, 1929.
291,178	The Carborundum Co., assignee of R. C. Benner and H. N. Baumann, Jr., all of Niagara Falls, N. Y. *Production of electrically conducting rods.* July 23, 1928.
291,204	Gewerkschaft Wallram, Abteilung Metallwerke, assignee of H. Voigtländer and O. Kaufels, all of Essen, Ruhr, Germany. *Carbide manufacture (carbides of refractory metals).* Aug. 28, 1925.
291,222	The National Iron Corp., Ltd., Toronto, Ont., assignee of J. H. Uhrig, Beverly, N. J. *Centrifugal pipe mold structure.* Nov. 30, 1928.
291,297	W. Rosenhain and J. D. Grogan, both of Teddington, Middlesex, England. *Aluminum processing.* Aug. 24, 1923.
291,306	W. J. Bell, Newaygo, Mich. *Sand conditioning system.* Nov. 16, 1927.
291,355	I. Rennerfelt, Djursholm, Sweden. *Electric furnace.* Aug. 22, 1926.
291,369	J. Washington, Kansas City, Kans. *Electric welding apparatus.* Oct. 29, 1928.
291,377	The Automatic Moulding Machines, Ltd., assignee of F. Breeden. both of Birmingham, Warwick, England. *Molding machine.* Feb. 2, 1928.
291,382	The Buckeye Steel Casting Co., assignee of E. W. Campion and A. H. Dierker, all of Columbus, Ohio. *Molding sand processing.* Nov. 26, 1928.
291,383	The Bundy Tubing Co., assignee of W. W. Anderson and A. Gardner, assignee of H. Bundy, all of Detroit, Mich. Tubing. Oct. 24, 1928.
291,429	The Paper & Textile Machinery Co., assignee of W. H. Millspaugh. both of Sandusky, Ohio. *Centrifugal casting machine.* Mar, 10, 1928.
291,430	The Paper & Textile Machinery Co., assignee of W. H. Millspaugh, both of Sandusky, Ohio. *Apparatus for making pipes.* July 26, 1928.
291,441	The Thompson Products, Inc., Cleveland, Ohio, assignee of R. E. Bissell, Cleveland Heights, Ohio. *Alloy steels and articles made therefrom (Fe-Cr-Ni-Si-C).* May 18, 1927.
291,442	The Thompson Products Inc., Cleveland, Ohio, assignee of R. E. Bissell, Cleveland Heights, Ohio. *Heat treatment (of austenitic alloy to make martensitic).* Jan. 16, 1928.
291,443	The Timken Roller Bearing Co., assignee of T. V. Buckwalter, both of Canton, Ohio. *Rolling mill.* Mar. 15, 1928.
291,444	The Timken Roller Bearing Co., assignee of T. V. Buckwalter, both of Canton, Ohio. *Rolling mill.* Mar. 15, 1928.
291,445	The Timken Roller Bearing Co., assignee of J. H. Van Campen, both of Canton, Ohio. Mar. 29, 1928.
291,505	H. Hillebrand, Berlin, Germany. *Regenerator heater.* Oct. 2, 1928.
291,571	The Dwight & Lloyd Sintering Co., Inc., New York, N. Y., assignee of R. W. Hyde, Summit, N. J. *Aluminum ore processing.* June 6, 1927.
291,579	The Globar Corp., assignee of H. N. Shaw, both of Niagara Falls, N. Y. *Electric heating apparatus.* Sept. 7, 1928.
291,600	The Parker Rust-Proof Co., Detroit, Mich., assignee of M. Green, Detroit, E. M. Jones, Adrian and H. H. Willard, Ann Arbor, all in Mich. *Rust-proofing compound.* Oct. 6, 1926.
291,601	N. V. Philips' Gloeilampenfabriken, assignee of H. Reerink, both of Eindhoven, Netherlands. Aug. 23, 1927.
291,607	Siemens & Halske Akt.-Ges., Berlin-Siemensstadt, Germany, assignee of R. Swinne, Berlin, Germany. *Electromagnetic body (single crystal).* Aug. 4, 1927.
291,633	G. D. Bengough and J. McA. Stuart, both of London, England. *Aluminum surface coloring process.* July 16, 1924.
291,674	H. Freeman, Shawinigan Falls, Que. *Sulfide ore processing.* Nov. 29, 1924.
291,765	La Compagnie de Produits Chimiques et Electrometallurgique Alais, Froges et Camargue, assignee of J. B. Suhr, both of Paris, France. *Electrical conductor (aluminum alloy).* Feb. 20, 1928.
291,777	I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany, assignee of R. Suchy, K. Staub and W. Moschel, Bitterfeld, Germany. *Carbon electrode protection.* Dec. 8, 1928.
291,782	The Hudson Motor Car Co., Detroit, Mich., assignee of O. J. Groehn, Grosse Pointe Park, Mich. *Sheet metal working machine.* Feb. 8, 1928.
291,827	E. G. Bek, assignee of E. Thoma, both of Pforzheim, Germany. *Metal product (base metal with precious metal surface).* Dec. 9, 1925.
291,850	R. H. Atkinson, London, England. *Precious metal extraction.* June 28, 1926.
291,856	H. Bohner, Hoyerswerda, Germany. *Aluminum wire.* Feb. 27, 1929.
291,869	W. A. Harrington, Leichhardt, near Sydney, New South Wales, Australia. *Metal molding apparatus.* May 31, 1928.
291,873	W. R. Hume, Melbourne, Victoria, Australia. *Pipe lining and molding method, and apparatus.* Jan. 26, 1929.
291,883	J. Kennedy, Pittsburgh, Pa. *Regenerative reversing furnace.* Dec. 3, 1927.
291,935	The American Machine & Foundry Co., New York, N. Y., assignee of W. J. Hawkins, Montclair, N. J. *Alloy and metal foil (Pb with 0.25 to 0.5 per cent Mg).* May 21, 1928.
291,955	S. Diescher & Sons, Pittsburgh, Pa. *Mill for piercing billets,* May 28, 1928.
291,962	The General Chemical Co., New York, N. Y., assignee of N. T. Wellman, Ridley Park, Pa. *Roasting furnace.* May 11, 1928.
291,963	The General Electric Co., Ltd., London, England, assignee of W. Singleton, Wembly Park, Middlesex, and G. C. Marris, Hampstead, Middlesex, England. *Electromagnet core (magnetic material coated with silicon).* Dec. 13, 1928.
291,964	The Goodyear Tire & Rubber Co., assignee of L. B. Sebrell.. both of Akron, Ohio. *Metal pickling method.* Nov. 23, 1927.
291,987	The Hume Steel Ltd., Melbourne, Victoria, Australia, assignee of E. S. Hume, Perth, West Australia. *Pipe lining or manufacturing apparatus.* Jan. 2, 1929.
292,009	The New Jersey Zinc Co., New York, N. Y., assignee of J. A. Singmaster, Bronxville, N. Y. and F. G. Breyer and E. H. Bunce, Palmerton, Pa. *Zinc. dust.* July 16, 1926.
292,015	The Paper & Textile Machinery Co., assignee of W. H. Millspaugh, both of Sandusky, Ohio. *Mold forming apparatus.* Mar. 16, 1928.
292,016	The Paper & Textile Machinery Co., assignee of W. H. Millspaugh, both of Sandusky, Ohio. *Pipe manufacture.* May 23, 1928.
292,017	The Paper & Textile Machinery Co., assignee of W. H. Millspaugh, both of Sandusky, Ohio. *Cast iron pipe.* Oct. 16, 1928.
292,032	La Société d'Expansion Technique, assignee of A. Portevin, both of Paris, France. *Steel pipe manufacture.* Nov. 8, 1927.

Danish Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
40,067	Societe Continentale Parker, Clichy, France. *Process for producing and regenerating rust-proofing baths containing phosphates.* Apr. 27, 1927, in the United States, May 10, 1926.

Patent No.	Patentee, Subject of Invention, and Filing Date
40,087	N. V. Philips' Gloeilampenfabriken, Eindhoven, Netherlands. *Process for making oxide cathodes.* Feb. 15, 1927, in the Netherlands, Apr. 6, 1926.
40,088	J. Dechesne, Rostock, Germany. *Apparatus used in the process for purifying molten iron from the cupola or hearth furnace.* June 28, 1926.
40,109	Ateliers de Construction Electrique de Charleroi, S. A., Charleroi, Belgium. *Transformer for electric arc welding.* Dec. 30, 1927, in Belgium Jan. 4 and Oct. 12, 1927.
40,112	J. Stone & Co., Ltd., Deptford, England. *Process and apparatus for the electrodeposition of metal on metal tubing.* Oct. 19, 1927. in Great Britain, Apr. 22 and July 13, 1927.
40,114	H. Hanemann, Berlin-Charlottenburg, Germany. *Process for making gray cast iron.* Dec. 1, 1926.
40,148	Societe Continentale Parker, Clichy, France. *Process for making a rust-proofing agent.* Apr. 27, 1927, in the United States, May 10, 1926.
40,160	R. J. Leary, Burlington, N. J. *Apparatus for charging molten metal into casting machines.* Jan. 12, 1927.
40,223	Sand Spun Patents Corp., New York, N. Y. *Process and machine for the centrifugal casting of hollow metal objects.* Aug. 24, 1925.
40,245	A. R. Trist, London, England. *Printing plate and process for making it.* Nov. 29, 1926, in Great Britain, Jan. 4, 1926.
40,246	R. H. V. Christensen, Copenhagen, Denmark. *Process and device for atomizing molten metals under pressure.* Feb. 29, 1928.
40,249	A. Kriwan, Mährisch-Ostrau-Privoz, Czechoslovakia. *Rolling mill with supports for working rolls.* Nov. 23, 1926.
40,255	A. McD. Duckham and Woodall-Duckham (1920) Ltd., London, England. *Recuperative annular muffle furnace.* Apr. 3, 1927, in Great Britain, Apr. 3, 1926.
40,305	E. Harbeck, Partille, Sweden. *Machine for cleaning metal objects.* Nov. 9, 1927.
40,334	Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. *Submarine cable with light-metal armor.* Apr. 25, 1928, in Germany, May 7, 1927.
40,363	A. Douty and J. H. Gravell, Ambler, Pa. *Process for pickling metals and pickling bath for the same.* Mar. 27, 1928, in the United States, Mar. 29, 1927.

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Patent No.	Patentee, Subject of Invention, and Filing Date
665,767	Centrifugal Castings, Ltd. *Improvements to Centrifugal machines for casting metal pipes.* Dec. 13, 1928.
665,768	Centrifugal Castings, Ltd. *Improvements to pouring devices for centrifugal casting machines.* Dec. 13, 1928.
665,779	Établissements Industriels E. C. Grammont and A. Grammont. *Process for making cathode filaments for vacuum tubes and filaments obtained by this process.* Mar. 24, 1928.
665,784	Compagnie Francaise des Forges de Chatillon, Commentry et Neuves-Maison. *Device for pouring slag.* Mar. 26, 1928.
665,804	A. Thomas. *Process for attaching fins to any sort of tubular object and its application to mounting of condensers.* Mar. 28, 1928.
665,821	G. Richard. *Use of cast iron reinforced with steel.* Dec. 13, 1928.
665,822	L. Renault. *Process for treating copper or bronze filings.* Dec. 13, 1928.
665,865	Centrifugal Castings, Ltd. *Improvements to apparatus for removing pipes or other cylindrical objects from the molds in which they have been cast.* Dec. 14, 1928.
665,875	K. Younghusband and John Summers & Sons, Ltd. *Improvements in the heating of rolls of metal-rolling mills.* Dec. 14, 1928.
665,882	Mannesmannröhren-Werke. *System for reinforcing shaft furnaces.* Dec. 14, 1928.
665,932	Aluminum, Ltd. *Improved process and apparatus for casting bimetallic ingots.* Dec. 15, 1928.
665,945	H. A. Dreffein. *Improvements to processes and apparatus for heating billets and the like.* Dec. 15, 1928.
665,968	H. Kuppers. *Apparatus for drying and preheating, particularly for foundry use.* Dec. 17, 1928.
666,036	A. Lentz. *Mixing device for molding sand.* Dec. 18, 1928.
666,068	Eisen- und Stahlwerk Hoesch Akt.-Ges. *Process for making thin, wide hot-rolled sheets.* Dec. 19, 1928.
666,101	J. Wikschtrom. *Machine for making nails.* Dec. 20, 1928.
666,135	Felten & Guilleaume Carlswerk Akt.-Ges. *Improvements to pouring ladles for metals.* Dec. 20, 1928.
666,165	Vereinigte Stahlwerke Akt.-Ges. *Means for increasing the shearing strength of riveted joints in light metals.* Dec. 21, 1928.
666,173	S. I. Levy and G. W. Gray. *Improvements in the treatment of iron pyrites.* Mar. 9, 1928.
666,194	Compagnie Francaise pour l'Exploitation des Procédés Thomson-Houston, Paris, France. *Improvements to the feed mechanisms of welding machines.* Nov. 22, 1928.
666,219	W. A. Loke. *Improvements in the reduction of ores and in the production of metals and alloys.* Dec. 13, 1928.
666,237	Thos. Firth & Sons, Ltd. *Improvements in the manufacture of metallic articles and to the alloys from which they are made.* Dec. 21, 1928.
666,271	E. Bornand and H. A. Schlaepfer. *Device for casting metals.* Dec. 21, 1928.
666,289	R. Sarazin, Neuilly-sur-Seine, France. *Arc welding electrode.* Dec. 22, 1928.
666,388	F. F. Gordon. *Improvements in the manufacture of billets, blooms, ingots or similar bodies of metal and the production of hollow bars or tubing from these bodies.*
666,419	Société Hahn & Kolb. *Machine for cleaning metallic objects, particularly parts of machinery.* Dec. 27, 1928.
666,420	Société Hahn & Kolb. *Cleaning machine, especially for metallic objects.* Dec. 27, 1928.
666,481	Società Giovanni Zanzi. *Valve for explosion motors and process for making it.* Dec. 27, 1928.
666,494	Société Anonyme Établissements Delatre & Frouard Réunis. *Bloom shears with adjustable upper blade and stationary lower blade.* Dec. 28, 1928.
666,567	A. G. Egler. *Improvements in the production of sound ingots.* Dec. 29, 1928.
666,600	Société Etablissements Metallurgiques Moizieux & Fils. *Cold rolling mill.* Dec. 24, 1928.
666,612	Imperial Chemical Industries, Ltd. *Improvements to processes for pickling metals.* Jan. 2, 1929.
666,654	Mme. F. A. De Silva, and C. G. Carlisle. *Improvements in the direct production of steel or steel alloys from titaniferous ores and iron sand.* May 18, 1928.
666,727	The Hamilton Press and Machinery Co. *Improvements to draw presses.* Dec. 15, 1928.
666,728	Felten & Guilleaume Carlswerk Akt.-Ges. *Improvements to foundry chill molds.* Dec. 15, 1928.
666,731	R. Schmitz. *Universal electric furnace for dental applications.* Dec. 15, 1928.
666,762	Société pour l'Utilisation Rationelle du Gaz (Surgaz). *Gas-heated tunnel for various thermal treatments.* Feb. 25, 1927.
666,789	Société Anonyme Commentry, Fourchambault & Decazeville. *Alloy with superior mechanical properties and high resistance to corrosion.* Mar. 30, 1928.
666,840	J. Morin. *Machine for making wire, bars, tubing, etc. out of lead or other fusible metals.* Apr. 6, 1928.
666,859	Compagnie Lorraine de Charbons pour l'Electricité, Paris, France. *Improvements to electrolytic metal-plating processes.* Apr. 11, 1928.
666,903	G. B. Shipley, and H. Alinder. *Improvements to deoxidizing annealing processes and the like for treating metal products.* Jan. 3, 1929.
666,907	Fried. Krupp Grusonwerk Akt.-Ges. *Process and apparatus for the magnetic separation of materials.* Jan. 3, 1929.
666,938	H. G. Flodin. *Process for making metallic sponge.* Jan. 4, 1929.
666,949	A. Pacz. *Process for producing aluminum and aluminum alloys.* Jan. 4, 1929.
666,957	Ingersoll Rand Co. *Forging machine.* Jan. 4, 1929.
666,967	Hume Steel, Ltd. *Improved process for welding or depositing metal with the electric arc.* Jan. 4, 1929.
666,975	The New Jersey Zinc Co. *Zinc alloy which is particularly suited to the fabrication of mechanically worked zinc products.* Jan. 5, 1929.
666,998	Felten & Guilleaume Carlswerk Akt.-Ges. *Improvements to devices for the preliminary treatment of wires for making cables free from torsional and tensile stresses.* Jan. 9, 1929.
666,999	L. Hoyois. *Hydraulic classifier for ore, coal and similar materials.* Jan. 5, 1929.
667,009	A. Décoret. *Adjustable draw-plate.* Jan. 7, 1929.
667,020	Air Reduction Co , Inc. *Welding process.* Jan. 7, 1929.
667,028	F. Hauptmeyer. *Products consisting of a mixture of a pulverized metal or alloy which is inert to chemical reagents and a binder.* Jan. 7, 1929.
667,049	A. Stahn. *Core binder.* Jan. 8, 1929.
667,067	Vanadium Corporation of America. *Improved process for making vanadium alloys.* Jan. 8, 1929.
667,068	Vanadium Corporation of America. *Improved process for making vanadium-aluminum-silicon alloys.* Jan. 8, 1929.
667,101	Vacuumschmelze G.m.b.H. *Refractory lining for the bottoms of metallurgical and other furnaces and process for making it.* Jan. 9, 1929.
667,103	Associated Lead Manufacturers, Ltd. *Improvements to apparatus for separating and classifying materials in suspension in fluids.* Jan 9, 1929.
667,111	Fried. Krupp Grusonwerk Akt.-Ges. *Process for obtaining earth metal compounds.* Jan. 9, 1929.
667,112	Fried. Krupp Grusonwerk Akt.-Ges. *Rollway, especially for rolling mill installations.* Jan. 9, 1929.
667,116	C. B. Pike. *Improvements to a method and an apparatus for stripping patterns and castings from sand molds.* Jan. 9, 1929.
667,144	L Tagliaferri. *Electromagnetically controlled hydraulic regulator for electrometallurgical furnaces.* Dec. 12, 1928.
667,147	F. W. Thompson. *Improvements to apparatus for heating metallic objects by electricity.* Dec. 17, 1928.
667,150	P. Durand. *Improvement to bronze gears having a hub of steel or malleable iron, and which are especially suitable for heavy-duty transmissions.* Dec. 27, 1928.
667,183	Electro-Metallurgical Ore Reduction, Ltd. *Improvements in the separation of gases or materials suspended in gases from metallurgical or other furnaces.* Jan. 9, 1929.
667,192	A. France. *Process and installation for the classification of ore, coal and the like.* Jan. 10, 1929.
667,450	Imperial Chemical Industries, Ltd. *Improvements in electrolytic deposition of metals.* Jan. 15, 1929.
667,453	P. Durand. *Metallurgical improvement to bronze gears.* Jan. 15, 1929.
667,466	Deutsche Gold und Silber Scheideanstalt, vorm. Roessler. *Process for cementing and hardening iron and steel and similar metals.* Jan. 15, 1929.
667,566	Metropolitan Vickers Electrical Co., Ltd. *Improvements to electric induction furnaces.* Jan. 17, 1929.
667,631	A. J. L. Motais de Narbonne. *Process for the electrolytic separation of nickel with simultaneous production of hydrogen.* Jan. 30, 1928.
667,685	W. I. Einstein (Ainstein). *Improvements to electrically conducting coatings, for the purpose of electroplating metal on to non-metallic objects.* Jan. 30, 1928.
667,686	W. I. Einstein (Ainstein). *Process for coloring metallic surfaces.* Jan. 30, 1928.
667,687	W. I. Einstein (Ainstein). *Improvements to electroplating apparatus.* Jan. 30, 1928.
667,703	Société d'Expansion Technique. *Crucible, especially for use in the centrifugal casting of pipes.* Apr. 20, 1928.
667,706	R. H. E. Leduc. *Refractory cement.* Apr. 21, 1928.
667,731	Girod. *Process and apparatus for casting ingots of steel or of any other metals or alloys.* Apr. 24, 1928.
667,826	Metallgesellschaft Akt.-Ges. *Material for molds for metals.* Jan. 21, 1929.
667,843	Fried. Krupp Akt.-Ges. *Austenitic chrome-nickel steels.* Jan. 21, 1929.

French Addition Patents

Patent No	Patentee, Subject of Invention, and Filing Date
34,824	N V. Philips' Gloeilampenfabrieken. *Process for making ductile bodies of tungsten or other refractory metal.* (Second addition to No. 561,169). Dec. 27, 1927.
34,826	A. L. Fichet. *Process for making links of ornamental chains from tubing by stamping and cutting.* (First addition to No. 608,594). Dec. 29, 1927.
34,880	Mannesmannröhren Werke. *Process for rolling tubing.* (First addition to No. 617,649. Jan. 20, 1928.
34,894	B. Talbot. *Improvements to metallurgical furnaces.* (First addition to No. 637,460). Jan. 25, 1928.
34,942	Gebrüder Siemens & Co. *Process for making bodies of carbon or mixtures of carbon and metal.* (First addition to No. 648,117). Feb. 13, 1928.
35,063	L. D. J. Tisseyre. *Electric salt bath furnaces for the heat treatment of magnetizable metals.* (First addition to No. 357,895). Jan. 18, 1928.
35,098	H. V. de Christiani. *Electrothermic installation with automatic regulator improving the power factor.* (Second addition to No. 648,812). Feb. 24, 1928.
35,152	Compagnie Francaise pour l'Exploitation des Procedes Thomson-Houston, Paris, France. *Improvements to processes and apparatus for arc welding and cutting.* (Third addition to No. 622,749). Jan. 9, 1928.
35,177	Compagnie Francaise pour l'Exploitation des Procedes Thomson-Houston, Paris, France. *Improvements to coating metals with a protective layer, especially one of metals used as getters.* (First addition to No. 631,276). Apr. 6, 1928.

German Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
479,389	A. Wacker Ges. für electrochemische Industrie G.m.b.H., Munich, Germany. *Machine for cleaning and degreasing metallic objects.* Sept. 21, 1927.
479,402	C. Lutz, Pfullingen, Württemberg, Germany. *Process for cementing iron and steel.* Oct. 29, 1926, in Austria Nov. 4, 1925.
479,406	Allgemeine Elektrizitäts Gesellschaft, Berlin, Germany. *Transformer with divided windings for welding or heating machines.* Apr. 26, 1927.
479,405	Allgemeine Elektrizitäts Gesellschaft, Berlin, Germany. *Clamping device for electric welding machines.* Mar. 4, 1925.
479,411	Hartstoff-Metall Akt.-Ges. (Hametag), Berlin-Cöpenick, Germany. *Device for producing granulated metal by breaking up a jet of molten metal.* Oct. 25, 1924.
479,421	Brück, Kretschel & Co., and O. Kippe, Osnabrück, Germany. *Process for briquetting fine ores, blast-furnace dust, roasted pyrites, and other smeltable substances.* Apr. 11, 1926.
479,444	W. Krefter, Witten, Ruhr, Germany. *Torch cutting machine.* Mây 1, 1927, in Kölner Messe, Mar. 20, 1927.
479,481	I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. *Recovery and refining of light metals.* (Addition to No. 403,802). Jan. 16, 1926.
479,521	E. Schlechte, Bucharest, Rumania. *Pneumatic sand machine for filling foundry flasks.* Sept. 15, 1927.
479,528	Th. Goldschmidt Akt.-Ges., Essen, Germany. *High-quality aluminum casting alloys,* Dec. 10, 1922.
479,554	Stahlwerke Bruninghaus Akt.-Ges., Westhofen, Westfalen, Germany. *Method of removing excess coating metal after galvanizing.* Dec. 6, 1927.
479,584	H. Geitmann, Berlin-Neukölln, Germany. *Device for brazing thin strips of steel such as band-saws by means of an electric current.* (Addition to No. 374,714). Nov. 27, 1924.
479,593	Demag Akt.-Ges., Duisburg, Germany. *Individual electric drive of roll trains, especially those of rolling mill installations.* Mar. 25, 1928.
479,614	Dr. C. Otto & Comp., G.m.b.H., Bochum, Germany. *Method of preventing increase of pressure in the gas passages of regenerative furnaces.* June 27, 1928.
479,624	P. Kreuzer, Gera, Germany. *Double molding machine.* Nov. 10, 1926.
479,625	J. Baritz Akt.-Ges., Saulgau, Württemberg, Germany. *Lifting device for mold boards.* May 14, 1927.
479,626	Viktoria-Hütte, Giffhorn & Diessner, Lüneberg, Hannover, Germany. *Snap flask for making flaskless sand molds.* Oct. 5, 1928.
479,627	D. Larner, Warren, Ohio. *Device for casting steel in evacuated chill molds.* Dec. 18, 1925.
479,628	C. Billand, Kaiserslautern, Rheinpfalz, Germany. *Machine for making castings, especially pipes, by centrifugal casting in cooled vertical molds.* May 30, 1926.
479,629	J. Holthaus, Gelsenkirchen, Germany. *Water-cooled mold for centrifugal casting.* Feb. 22, 1927.
479,630	C. D. Pettis, New York, N. Y. *Permanent mold made up of separate sections.* June 16, 1925.
479,631	C. D. Pettis, New York, N. Y. *Permanent mold made up of separate sections.* June 16, 1925.
479,632	J. Polak, Prague, Czechoslovakia. *Compressed air die casting machine.* Nov. 6, 1926.
479,661	Zinnwerke Wilhelmsburg G.m.b.H., Wilhelmsburg a.d. Elbe, Germany. *Working up converter dusts, especially those consisting of mixtures of oxides.*
479,662	Chemisches Laboratorium "City," Berlin, Germany. *Process for making a nickelizing material for metals, to be applied while wet.* Oct. 15, 1925.
479,666	Maschinenbau Akt.-Ges. vorm Ehrhardt & Sehner, Saarbrücken, Germany. *Three-journal bearing mounting for heavy duty bearings, especially those for roll-necks.* Jan. 12, 1928.
479,672	T. G. Martyn, Johannesburg, Transvaal, South Africa. *Apparatus for separating the solid constituents from slimes.* Apr. 17, 1926.
479,675	Vereinigte Stahlwerke Akt.-Ges., Düsseldorf, Germany. *Device for turning sheets or other flat objects in their own planes while being transported on moving conveyor belts.* Sept. 10, 1927.
479,676	R. Bosch Akt.-Ges., Stuttgart, Germany. *Process for hot pressing metal bars and simultaneously putting on a jacket of another metal.* Apr. 20, 1926.
479,724	Piepmeyer & Co., Komm.-Ges., Kassel-Wilhelmshöhe, Germany *Method of determining the position and shape of ore deposits or rock strata by observations on sound waves.* Dec. 28, 1922.
479,741	J. Hess, Vienna, Austria. *Process for making subdivided cores for Pupin coils and the like from magnetic particles covered with a non-magnetic metallic layer and an electrically insulating layer.* Dec. 12, 1925.
479,742	J. Hess, Vienna, Austria. *Process for making subdivided magnetic cores from magnetic particles covered with a layer of fusible metal by electroplating.* Dec. 12, 1925.
479,746	F. Ellinger, Buchberg, Salzberg, Germany. *Stirring device for fusion-electrolysis baths.*
479,774	Ilseder Hütte, Gross Ilsede, Hannover, Germany. *Device for the simultaneous decomposition and refining of soft clayey ores.* Dec. 15, 1925.
479,779	Eumoco Akt.-Ges. für Maschinenbau, Schlebusch-Manfort, and A. Schneider, Düsseldorf, Germany. *Method of upsetting thickened places on tubing.* Sept. 14, 1927.
479,785	Allgemeine Elektrizitäts Gesellschaft, Berlin, Germany. *Method of electric resistance welding of pieces which cross each other.* Jan. 12, 1927.
479,823	Fried. Krupp Grusonwerk Akt.-Ges., Magdeburg-Buckau, Germany. *Device for placing ingots in an extrusion press.* June 10, 1926.
479,844	Eisen- und Hüttenwerke Akt.-Ges., Bochum, Germany. *Conveyor for transporting the partly rolled sheet from the roughing rolls to the finishing rolls of sheet mills.* Dec. 22, 1927.
479,851	A. Besta, Duisburg, Germany. *Method of, and apparatus for, heating and then cooling, especially annealing, metals in a heating furnace filled with an inert gas.* Mar. 1, 1925.
479,852	Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. *Annealing furnace for the continuous annealing of tubing, bars, and the like.* Sept. 3, 1925.
479,895	S. Ioshimoto, Aki-Gun; T. Okumura, Kobe-Shi; and S. Nakamura, Muko-Gun, Japan. *Process for making building and paving stones from copper slag.* Aug. 27, 1926, in Japan June 2, 1926.
479,968	R. Brede, Köln, Germany. *Silicon-brass bearing.* May 11, 1924.
479,973	H. Fontaine, Montreuil, Seine, France. *Thread-rolling machine.* Feb. 5, 1926, in France Jan. 4, 1926.
480,029	Standard Telephone and Cables, Ltd., London, England. *Method of making magnetic materials, especially for the cores of loading coils for cables, consisting of a nickel-iron alloy mixed with an insulating material.* Apr. 8, 1927, in the United States Apr. 10, 1926.
480,038	Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. *Furnace for the continuous bright-annealing of bundles of rods and tubing.* Aug. 15, 1926.
480,153	H. Töpper, Berlin, Germany. *Autogenous welding and cutting torch which is convertible into an underwater torch.* Jan. 29, 1929.
480,078	Schloemann Akt.-Ges., Düsseldorf, Germany. *Device for withdrawing, conveying, and turning ingots.* Mar. 22, 1928.
480,087	Freier Grunde Eisen- u. Metallwerke G.m.b.H., Neunkirchen, Germany. *Melting furnace with a fore-hearth from which iron and slag flow continuously in different directions.* June 19, 1925.
480,118	Badische Maschinenfabrik und Eisengiesserei vorm. G. Sebold & neff., Durlach, Baden, Germany. *Sand-slinger molding machine.* Oct. 9, 1926.
480,128	W. Kroll, Luxemburg. *Production of metallic beryllium by displacement from beryllium-alkali double fluorides in the fused condition by another metal.* Sept. 29, 1926.
480,203	Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. *Supporting ring for the crucibles of electric furnaces.* Dec. 31, 1927, in the United States Feb. 16, 1927.
480,204	Halbergerhütte G.m.b.H., Brebach a. d. Saar, Germany. *Mechanism for carrying along the pouring trough of centrifugal casting machines.* Oct. 5, 1926.
480,284	Heinrich Lanz Akt.-Ges., Mannheim, Germany. *Gray cast iron, improved by the addition of nickel.* Dec. 2, 1923.
480,287	Metallwerk Plansee G.m.b.H., Reutte, Tyrol. *Production o molybdic or tungstic acid.* Apr. 27, 1926.
480,292	Engelhardt Achenbach sel. Söhne G.m.b.H., Buschhütten, Kr. Siegen, Westfalen, Germany. *Strip rolling mill mechanism.* June 3, 1927.
480,293	Vereinigte Aluminium Werke Akt.-Ges., Lautawerk, Lausitz, Germany. *Method of obtaining uniform strength in rolled wires of aluminum and its alloys.* Feb. 28, 1928.
480,294	Fried. Krupp Grusonwerke Akt.-Ges., Magdeburg-Buckau, Germany. *Reciprocating conveyor with up-and-down motion, particularly for carrying rolled bars from cooling beds.* May 6, 1928.
480,295	Machinenfabrik Sack G.m.b.H., Düsseldorf-Rath, Germany. *Device for cross-motion of material being rolled.* May 2, 1928.
480,311	W. Kurze, Hannover, Germany. *Sand-slinging machine.* July 7, 1927.
480,340	Maschinenfabrik Sach G.m.b.H., Düsseldorf-Rath, Germany. *Skew rolling mill.* Apr. 13, 1927.
480,341	Schloemann Akt.-Ges., Düsseldorf, Germany. *Articulated coupling for rolling mills.* Dec. 6, 1927.
480,389	Gebrüder Fessler, Pforzheim, Germany. *Method of degreasing objects.* June 2, 1928.
480,390	F. A. Oddie, Southampton, England. *Machine for bending long pieces of metal such as tubing, sections, and the like.* June 6, 1926.
480,420	L. Siméant, Paris, and H. Kuppel, Clichy, France. *Process for the electrolytic renewal of the surface of used copper-plated printing rolls.* May 18, 1926.
480,425	Erz- und Kohle-Flotation G.m.b.H. *Apparatus for working up material by the flotation process.* Nov. 17, 1926.
480,428	G. Burkhardt, Herrenalb, Württemberg, Germany. *Machine for rolling tubing, with cylindrical working rolls and conical mandrel point.* (Addition to 453,124). Aug. 28, 1928.
480,432	Allgemeine Elektricitäts Gesellschaft, Berlin, Germany. *Electric salt bath furnace.* Aug. 27, 1926.
480,468	K. Gruber, Rheydt, Rhld., and A. Stappen, München-Gladbach, Germany. *Extractor for pilger rolling mills.* Sept. 16, 1925.

Patent No.	Patentee, Subject of Invention, and Filing Date
480,469	H. Junkers, Dessau, Germany. *Machine for piling sheet metal.* (Addition to 477,153.) Aug. 12, 1925, in Sweden July 24, 1925 (claims 1–3).
480,481	E. Hodeige, Jemeppe-sur-Meuse, Belgium. *Process for classifying coal, ore and the like in a flow box, and apparatus therefor.* Oct. 22, 1924, in Belgium Apr. 17, 1924.
480,482	H. Ehrhardt, Zella-Mehlis, Germany. *Device for making hollow castings for drawing down.* July 30, 1927.
480,540	S. Paulini, Beuthen O.-S., Germany. *Furnace for electrothermic processes.* Nov. 13, 1926.
480,549	Aluminium Industrie Akt.-Ges., Neuhausen, Switzerland. *Process for the electrolytic recovery of pure aluminum.* Nov. 23, 1926.
480,581	I. Block, Berlin-Lichterfelde, Germany. *Method of simultaneously heating work and mold in the aluminothermic welding of rails.* May 9, 1924.
480,593	E. Schwartz, Stöhna-Erlhof, Bez. Leipzig, Germany. *Automatic deep-drawing press.* Jan. 6, 1929.
480,594	F. Beér, Dresden, Germany. *Draw-press mechanism* Mar. 9, 1928.
480,617	K. Schmidt, Neckarsulm, Württemberg, Germany. *Melting furnace which is rotatable through 360° about an inclined axis.* Sept. 22, 1927.
480,618	E. Dreves, Düsseldorf-Oberkassel, Germany. *Chamber oven for production of dry air.* Dec. 18, 1924.
480,691	Heraeus-Vacuum-Schmelze Akt.-Ges. and W. Rohn, Hanau a.M., Germany. Dec. 16, 1924.
480,713	I. Cavalli, Padua, Italy. *Recovery of mercury in the wet way from roasted or unroasted ore.* Sept. 21, 1927, in Italy Sept. 24, 1926.
480,720	A. Pacz, Cleveland, Ohio. *Method of providing metal consisting wholly or chiefly of aluminum, with an irregular mottled coating.* Dec. 2, 1926, in the United States Dec. 15, 1926.
480,722	A. Rink, Osnabrück-Kamp, Germany. *Tire-annealing furnace.* May 16, 1928.
480,750	Siemens-Planiawerke Akt.-Ges. für Kohlefabrikate, Berlin-Lichtenberg, Germany. *Method of making heating elements with enlarged ends.* Apr. 11, 1926.
480,754	R. Blasberg, Merscheid, near Ohligs, Germany. *Galvanizing apparatus.* Nov. 17, 1926.
480,768	Allgemeine Elektricitäts Gesellschaft, Berlin, Germany. *Electric annealing or hardening furnace.* Apr. 22, 1927.
480,803	Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. *Electric furnace.* Aug. 10, 1926.
480,831	C. Rein, Hannover, Germany. *Pouring ladle for molten metal, particularly iron.* May 7, 1927.
480,856	W. Buess, Hannover, Germany. *Cylindrical drum furnace rotatable through 360°, for melting metals and alloys.* July 17, 1926.
480,900	Piel & Adey G.m.b.H., Solingen, Germany. *Method of making section bars of refractory alloys with over 50 percent copper, by casting in a chill mold.* May 23, 1923.
480,956	Osnabrücker Dampfkesselfabrik Julius Meyer, Osnabrück, Germany. *Machine for working metal bars, with revolving striking elements.* Aug. 28, 1927.
480,957	Serck Radiators, Ltd., and O. Serck, Birmingham, England. *Tubing extrusion press.* Aug. 19, 1926, in Great Britain Sept. 10, 1925.
480,973	R. Bührer, Willisau, Lucerne, Switzerland. *Oil-burner, especially for metal-melting hearths.* Nov. 2, 1927.
480,990	E. Haas, Gotha, Thür., Germany. *Machine for cleaning metal parts.* Feb. 1, 1927.
480,991	L. Kochs, Düsseldorf-Oberkassel, Germany. *Machine for making metal castings.* Apr. 20, 1928.
480,992	Rasselsterner Eisenwerke-Gesellschaft Akt.-Ges., and E. Mischke, Neuweid-Rasselstern, Germany. *Method of using siphons for conveying fusible substances which are solid at normal temperatures.* Nov. 8, 1928.
480,993	H. Prohahn, Gelsenkirchen, Germany. *Method of treating centrifugally cast pipes.* Feb. 22, 1927.
480,995	A. Pacz, Cleveland, Ohio. *Process for coating and coloring metals.* Apr. 17, 1927, in the United States, Apr. 16, 1926.
480,996	E. Cumberland, Kingston Hill, England. *Means for protecting metallic objects on shipboard against corrosion by stray currents.* Mar. 4, 1927, in Great Britain, June 15, 1926.
481,035	H. Koch, Strassburg, Alsace. *Gas-heated crucible furnace, with hollow jacket.* Apr. 24, 1927.
481,133	Siemens & Halske Akt.-Ges., Berlin-Siemensstadt, Germany. *Method of increasing the strength of metallic bodies consisting of a few large crystals.* July 22, 1923.
481,161	F. Bäuml, Nuremberg, Germany. *Means for carrying off acid fumes from dipping and pickling installations.* (Addition to No. 426,205.) Apr. 22, 1928.
481,190	Firma Leopold Erlenbach, Fürth i. B., Germany. *Process for making genuine gold leaf.* Jan. 27, 1928.
481,211	Fried. Krupp Grusonwerk Akt.-Ges., Magdeburg-Buckau, Germany. *Working up complex ores.* Aug. 8, 1925.
481,212	Fried. Krupp Akt.-Ges., Essen, Ruhr, Germany. *Production of tools made of hard-metal alloys produced by sintering.* Dec. 13, 1925.
481,228	M. Lovoye, Huy, Belgium. *Tubular furnace for treatment of ores, particularly aluminum ores.* Aug. 11, 1926.
481,332	Friedrich Siemens Akt.-Ges., Berlin, Germany. *Reversing valve for regenerative furnaces.* Feb. 25, 1928.
481,334	H. Burchartz, Gelsenkirchen, Germany. *Method of and machine for the centrifugal casting of pipes in thin-walled chill molds.* Apr. 10, 1927.
481,363	P. Haessler, Nuremberg, Germany. *Method of making composite castings.* May 9, 1926.
481,394	W. Witter, Halle a.d.S., Germany. *Process for the treatment and refining of tin ores and tin-bearing material.* Sept. 1, 1925.
481,403	Engelhardt Achenbach sel. Söhne G.m.b.H., Buchhütten, Kr. Siegen i.W., Germany. *Entrance guiding device for rolling mills.* Jan. 1, 1928.
481,404	Engelhardt Achenbach sel. Söhne G.m.b.H., Buchhütten, Kr. Siegen i.W., Germany. *Entrance guiding device for rolling mills.* (Addition to No. 481,403.) June 23, 1928.
481,459	Langbein-Pfanhauser-Werke Akt.-Ges., Leipzig, Germany. *Method of and machine for transferring goods from one conveyor system to another, especially in continuous galvanizing plants.* Mar. 4, 1928.
481,505	Siemens & Halske Akt.-Ges., Berlin-Siemensstadt, Germany. *Improvement of copper-magnesium alloys.* July 15, 1927.
481,539	A. Pfretsschner G. m. b. H., Pasing, near Munich, Germany. *Electric welding machine.* June 19, 1926.

Italian Patents

Patent No.	Pantentee, Subject of Invention, and Filing Date
261,683	R. Dufour, Paris, France. *Improvements to electric furnaces, especially to high-frequency induction furnaces.* July 28, 1927.
261,698	Vereinigte Stahlwerke Akt.-Ges., Düsseldorf, Germany. *Silicon copper steel, particularly adapted for structural purposes.* May 20, 1927, in Germany May 22, 1926 (in name of W. Hülsbruch).
261,717	Siemens-Schuckertwerke G. m. b. H., Berlin-Siemensstadt, Germany. *Apparatus for determining the level of a liquid.* May 25, 1927, in Germany Dec. 23, 1926.
261,734	Mansfeld Akt.-Ges. für Bergbau u. Hüttenbetrueb, Eisleben, Merseburg; and O. Busse, Burgoerner, near Hettstedt, Süd Harz, Germany. *Mill for rolling large blooms or ingots into sheet and strip.* June 9, 1927.
261,740	F. Wüst. *Process for refining cast iron.* June 30, 1927, in Germany July 17, 1926.
261,759	O. Meyer-Keller & Co., Lucerne, Switzerland. *Process for making corrugated tubing.* Aug. 5, 1927.
261,771	F. Salerno, Naples. Italy. *Melting furnace fired with vaporized oil and steam.* Mar. 18, 1926.
261,788	F. Krupp Grusonwerk Akt.-Ges., Magdeburg-Buckau, Germany. *Process for recovering lead from sulfide ores and metallurgical residues.* July 7, 1927.
261,823	Inidana Steel & Wire Co., Muncie, Ind., assignee of F. M. Crapo. *Process for galvanizing iron and steel objects and products produced.* Apr. 1, 1927, in the United States July 15, 1926.
261,837	Aluminum Company of America, Pittsburgh, Pa., assignee of E. H. Dix, Jr. *Process for making castings of corrosion-resistant aluminum alloys.* June 2, 1927, in the United States Jan. 22, 1927.
261,883	F. D. Corbin; Llanelly Foundry & Engineering Co., Ltd.; and R. Nevill & Co., Ltd., Llanelly, Carmathenshire, Wales. *Improvements to rolls for rolling metals.* June 30, 1927, in Great Britain July 7, 1926.
261,928	Metallbank und Metallurgische Gesellschaft Akt.-Ges., Frankfurt a.M., Germany. *Process for producing protective layers on metals by diffusion of aluminum or aluminum alloys.* June 14, 1927, in Germany June 15, 1926.
261,941	K. Karius, Achern, Baden, Germany. *System for rolling shapes, part of whose cross-section is hollow.* (First addition to No. 255,639, filed Jan. 7, 1927). Jan. 7, 1927, in Germany Mar. 11, 1926 (German Patent No. 438,320).
261,956	U. De la Pierre, Turin, Italy. *Steel which is resistant to corrosion and to high temperatures.* Dec. 30, 1927.

Norwegian Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
46,444	Siemens & Halske Akt.-Ges., Berlin-Siemensstadt, Germany. *Induction furnace.* June 27, 1927.
46,447	H. E. Coley, London, England. *Process for the reduction of ores.* Jan. 13, 1928.
46,453	I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. *Method of bending magnesium alloy shapes.* Jan. 7, 1928, in Germany Jan. 28, 1927.
46,455	J. W. Ericsson, Svedala, Sweden. *Machine for crushing ore stone and the like.* Oct. 7, 1927.
46,010	A/S. Norsk Staal (Elektrisk-Gas-Reduktion), Oslo, Norway. *Shaft furnace for treating solid materials with gases.* Aug. 22, 1927.
46,250	Borgestad Fabrikken, Borgestad, Norway, assignee of V. M. Goldschmidt. *Refractory material and process for making it.* Feb. 19, 1927.
46,515	I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany *Machine for forming shapes out of magnesium alloy sheet.* Jan. 6, 1928, in Germany Jan. 28, 1927.
46,528	Electrical Research Products, Inc., New York, N. Y. *Magnetic material.* Aug. 25, 1925.
46,529	Electrical Research Products, Inc., New York, N. Y. *Magnetic material.* Sept. 8, 1925.
46,530	Siemens-Schuckertwerke G. m. b. H., Berlin-Siemensstadt, Germany. *Perforated blocks for holding heating resistances.* Apr. 13, 1927.
46,547	Guggenheim Bros., New York, N. Y. *Process for concentrating ores.* May 12, 1927.
46,548	H. S. Thomas and W. R. Davies, Glamorgan, Wales. *Machine for straightening or bending sheet metal.* Sept. 29, 1927.
46,597	Udylite Process Co., Kokomo, Ind. *Process for electroplating with cadmium from a potassium cyanide cadmium bath.* Mar. 26, 1927, in the United States Mar. 31, 1926.
46,624	F. Krupp Akt.-Ges., Essen-Ruhr, Germany. *Method of making castings of corrosion-resistant steel (for example of chrome-nickel steel).* Jan. 25, 1927, in Germany Feb. 18, 1926.
46,630	Société "Lap," Paris, France. *Process for metallizing the surface of aluminous cement or other hydraulic cement.* Oct. 25, 1924, in France May 31, 1924.

Swedish Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
66,955	G. N. Svensson, and S. C. G. Ekelund, Stockholm, Sweden. *Process and plant for the reduction of ore and the like (for example direct production of iron from ore).* May 16, 1925.
66,956	Siemens Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany, assignee of J. Schnepf. *Bright-annealing furnace using a protective gas.* Nov. 28, 1927, in Germany Dec. 9, 1926.

Patent No.	Patentee, Subject of Invention, and Filing Date
66,974	A. Roitzheim, and W. Remy, Berlin-Oberschöneweide, Germany. *Process and furnace for the treatment of zinc ores and zinciferous materials.* Oct. 22, 1926, in Germany Nov. 13, 1925.
67,002	Gewerkschaft Wallram, Essen-Ruhr, Germany, assignee of H. Voigtländer and O. Kaufels. *Process for making carbides of refractory metals.* July 9, 1925, in Germany Sept. 8, Nov. 14, 1924 and Jan. 5, 1925.
67,007	Eisen und Stahlwerk Hoesch Akt.-Ges. in Dortmund, Dortmund; and W. Heidenhain (inventor), Hagen, Germany. *Method of hardening objects of iron, steel and other ferrous magnetic materials.* Dec. 20, 1927, in Germany Dec. 28, 1926.
67,032	R. Appel, Berlin, Germany. *Process for the electrolytic chromium plating of metals.* Mar. 12, 1926, in Germany Nov. 26, 1925.
67,033	R. Appel, Berlin, Germany. *Process for the electrolytic chromium plating of metals.* July 20, 1927, in Germany July 21, 1926.
67,034	Madsenell Corp., Long Island City, N. Y. *Process for treating the surfaces of objects made of iron or ferrous alloys.* June 29, 1925.
67,036	H. Schultz, Berlin-Lankwitz, Germany. *Mold for alumino-thermic welding.* Jan. 14, 1928, in Germany Apr. 6, 1927.
67,050	F. C. Langenberg (inventor), Cambridge, Mass., and T. C. Dickson, Watertown, Mass. *Method and apparatus for increasing the elastic limit of gun tubes and other hollow objects made of steel or other metals.* Aug. 1, 1925.
67,059	W. R. Saltrick, Parley, England. *Process for making refined alloys of iron with chromium or tungsten or with both of these metals.* Mar. 17, 1923, in Great Britain Mar. 17, Apr. 1, and June 30, 1922.
67,071	H. E. Coley, London, England. *Process for reducing metals from ores, oxides or the like.* Nov. 6, 1922, in Great Britain Nov. 10, 1922 and Sept. 6, 1923.
67,072	G. Michel, Bagneaux, France. *Method of protecting baths of easily oxidizable metals against oxidation.* Aug. 9, 1926, in France Aug. 18, 1925 and May 11, 1926.
67,106	H. Harris, London, England. *Process for working up melts or fused salt mixtures obtained by treating metals or their ores with alkali hydroxides.* (Applied especially to antimony and tin). Nov. 22, 1923, in Great Britain Dec. 4, 1922.
67,107	E. Breuning, Hagen, i.W., Germany. *Process for the recovery of nickel from sheet consisting of alternate layers of copper and nickel.* June 7, 1927, in Germany July 10, 1926.
67,108	T. W. S. Hutchins, Davenham, Chestershire, England. *Process for the electrodeposition of metals.* (Addition to No. 63,235). Aug. 30, 1924, in Great Britain Mar. 4, 1924.
67,140	Elektromotorenwerke Hermann Gradewitz, Berlin, Germany., assignee of O. Zein. *Tubing press.* Jan. 4, 1928, in Germany June 1, 1927.
67,144	A. Rotter, Witkowitz, Czechoslovakia. *Cooling device for furnaces, especially open-hearth and the like furnaces.* Sept. 25, 1925.
67,156	Aktiebolaget Oskarshamns Kopparwerk, Oskarshamn, Sweden. assignee of S. O. Holmqvist. *Process for refining cementation* Oct. 3, 1925.
67,162	R. Eberhard, Munich, Germany. *Process for making a paint for the deoxidation of rust or other metallic oxides.* Aug. 6, 1926, in Germany Mar. 29, 1926.
67,175	H. G. Flodin, Roslags-Näsby, and E. G. T. Gustafsson, Stockholm, Sweden. *Process for reducing metals of the iron group.* Apr. 8, 1924.
67,190	New Process Multi-Castings Co., New York, N. Y., assignee of J. R. Wood. *Molding machine.* Feb. 11, 1926, in the United States May 29, 1925.
67,195	F. Frupp Grusonwerk Akt.-Ges., Magdeburg-Buckau, Germany, assignee of F. Johannsen. *Process for the recovery of easily volatilized metals from sulfide ores, smelter products and residues of all kinds.* Apr. 30, 1925, in Germany May 30, 1924.
67,205	American Machine and Foundry Co., New York, N. Y., assignee of E. R. Millring. *Process for making molten metallic baths for coating metal objects.* Dec. 16, 1926.
67,236	H. Barthel, Schweinfurth a.M., Germany. *Method of producing metallic objects by a combined casting and pressing operation.* Oct. 4, 1926, in Germany Mar. 20, 1926.
67,286	N. V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands, assigneee of E. H. Reerink. *Process for coating bodies with platinum.* Aug. 17, 1927, in the Netherlands Oct. 14, 1926.
67,287	N. V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands, assignee of E. H. Reerink. *Process for depositing one or more of the metals rhodium, iridium, osmium, or ruthenium on to bodies* May 4, 1928, in the Netherlands Oct. 20, 1927.
67,327	H. Grünewald, Hilchenbach, Germany. *Annealing furnace for metals, etc.* Dec. 10, 1927, in Germany Dec. 11, 1926.
67,337	G. E. R. Nilson, Stockholm, Sweden, assignee of S. D. Danieli. *Process for producing low-carbon metals and alloys.* Apr. 28, 1926.
67,345	"Le Petrole Synthetique" Soc. An., Paris, France, assignee of L. Wittouch. *Method of producing a refractory coating on metallic or other surfaces.* Nov. 16, 1927, in France Nov. 24, 1926 and Oct. 24, 1927.
67,358	N. V. Handelmaatschappij "Feriron," Rotterdam, Netherlands, assignee of T. Levoz. *Process for making low-carbon iron from the ore.* Jan. 31, 1924, in Belgium Feb. 1, 1923.
67,359	W. H. Smith, Detroit, Mich. *Process and apparatus for the reduction of metallic oxides.* Oct. 1, 1926, in the United States, Feb. 17, 1926.
67,366	K. G. Sjöberg, Falun, Sweden. *Electric furnace arrangement* July 1, 1927.
67,371	H. G. E. Cornelius, assignee of G. H. Flodin, Stockholm, Sweden. *Process for producing low-carbon metals and alloys.* (Addition to No. 64,288.) July 27, 1923.
67,391	Elektrodenmaschinen G. m. b. H., Hamburg, Germany, assignee of O. F. A. E. Grumpelt. *Method of cutting metal with the aid of an electric current.* Mar. 9, 1925.
67,418	Maschinenfabrik Akt.-Ges. Richard Herz, Vienna, Austria, assignee of A. Lukas. *Wire-rod rolling mill.* Nov. 2, 1927, in Austria Nov. 3, 1926.
67,440	K. Springorum, Berlin-Dahlem, Germany. *Alloy for making tableware.* Mar. 20, 1928.
67,462	Flodinjern Aktiebolaget, Stockholm, Sweden, assignee of E. G. T. Gustafsson. *Process for producing metals.* May 16, 1925.
67,465	Electrical Research Products, Inc., New York City, N. Y., assignee of G. W. Elmen. *Magnetic metal and submarine cable loaded therewith.* Sept. 1, 1925.
67,467	Scovill Manufacturing Co., Waterbury, Conn., assignee of M. Bennett. *Electric furnace.* July 22, 1925.
67,491	L. T. Brearley, Sheffield, England. *Process for fabricating hollow metal bars and product produced by this process.* Mar. 21, 1927, in England Mar. 26, 1926.
67,505	Aluminium Industrie Akt.-Ges., Neuhausen, Switzerland, assignee of J. Weber and V. Zeerleder. *Process for the electrolytic recovery of pure aluminum in coherent form from crude aluminum, alloys, etc.* Sept. 13, 1927.
67,548	Mannesmannröhren Werke Akt.-Ges., Düsseldorf, Germany. *Mandrel for rolling mills.* Sept. 5, 1927, in Germany June 14, 1927.
67,559	R. J. Leary, Burlington, N. J. *Casting machine.* Jan. 11, 1927.

Swiss Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
131,372	Maschinenfabrik Winkler, Fallert & Co. Akt.-Ges., Bern, Switzerland. *Drive for automatic casting machines.* Mar. 29, 1928, in Germany May 21, 1927.
131,405	Aluminium Industrie Akt.-Ges., Neuhausen, Switzerland. *Process for the electrolytic production of aluminum from metallic materials containing aluminum.* Jan. 24, 1927, in Germany Jan. 27, and Nov. 22, 1926.
131,406	W. H. Nichols, New York, N. Y. *Molding machine.* Jan. 24, 1928.
131,408	R. Sarazin, Neuilly-sur-Seine, France. *Electric arc welding apparatus.* Dec. 5, 1927, in France Dec. 18, 1926 and May 13, and July 1, 1927.
131,457	Akt.-Ges. Brown Boveri & Cie., Baden, Switzerland. *Gas-tight current lead-in for electric bright-annealing furnaces.* Apr. 17, 1928, in Germany May 25, 1927.
131,493	I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. *Process for making a catalyst which is especially adapted to the reduction and hydrogenation of organic compounds.* (Addition to 127,516). Sept. 23, 1927, in Germany Dec. 14, 1926 and Apr. 28, 1927.
131,624	T. R. Haglund, Stockholm, Sweden. *Process for producing metals and alloys.* Jan. 30, 1928, in Sweden Feb. 1, 1927.
131,625	Meehanite Metal Corp., Chattanooga, Tenn. *Process for making cast iron.* Feb. 22, 1928.
131,626	W. Koehler, Cleveland, Ohio. *Process for the production of metallic magnesium.* Aug. 8, 1927.
131,627	Gotthardwerke Akt.-Ges. für Elektrochemische Industrie, and A. A. Paolini, Bodio, Tessin, Switzerland. *Process for making a reducing agent for the reduction of oxidic metal compounds from aluminous raw material.* Apr. 26, 1927.
131,628	C. Brackelsberg, Milspe, Germany. *Method and means for heating rotary melting furnaces.* Feb. 29, 1928, in Germany Mar. 9, and Apr. 1, 1927.
131,630	Trefileries & Laminoires du Havre, Anciens Établissements Lazare Weiller Soc. Coopérative de Rugles et la Canalisation Electrique Reunis, Paris, France. *Process for making metallic powders.* Nov. 28, 1927.
131,615	Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany *Submarine cable with light-metal sheath.* Apr. 23, 1928, in Germany May 7, 1927.
131,690	Autogen Endress Akt.-Ges., Horgen, Switzerland. *Welding and cutting torch.* Feb. 6, 1928.
131,827	F. von Wurstemberger, Zürich, Switzerland. *Process for freeing passivity baths of undesired metal compounds, especially those of copper.* Apr. 12, 1928.
131,828	M. Bolliger, Nieder-Gerlafingen, Switzerland. *Quick-metallizing apparatus.* May 19, 1928.
131,868	W. M. Still & Sons, Ltd., and M. T. Smith, London, England *Machine for polishing metal ware.* Dec. 22, 1927, in Great Britain Apr. 25, 1927.

Reviews of Manufacturers' Literature

In this department we shall list each month a selection of the catalogs, books, treatises and other printed matter issued by manufacturers which, in our judgment, should be of interest to the readers of METALS & ALLOYS. *Unless otherwise noted, any of the items listed may be secured free upon application to the issuing firm. Manufacturers who have not yet sent in their printed matter for consideration by the editor of this department are invited to do so, and it is suggested that* METALS & ALLOYS *be placed on the regular mailing list so that advance copies of any material of interest to the metallurgical field may automatically come to this department.*—EDITOR.

Kewaunee Book of Laboratory Furniture.—New book constituting a complete compendium on the subject. Layouts with complete data on every item of furniture required in the modern laboratory. 455 pages. Substantial cloth binding. Kewaunee Mfg. Co., Kewaunee, Wis.

Platinum Laboratory Wares.—Catalog No. 15 covering complete line of platinum equipment, temperature conversion tables and much other useful information. American Platinum Works, Newark, N. J.

Coated Arc Welding Electrodes.—Bulletin describing arc welding process as applied to the fabrication and repair of metals. Technical data. Arcos, Inc., La Crosse, Wisconsin.

A New Stainless Steel.—Bulletins announcing Carpenter stainless steel Nos. 1, 2, 3, 4 and 5. Physical properties and other important data. Carpenter Steel Co., Reading, Pa.

Zinc Metals and Alloys.—Brochure punched for standard size note book containing important information on subject indicated. New Jersey Zinc Co., 161 Front St., New York, N. Y.

Published by the same firm, "Rolled Zinc." Companion publication to the above with data on rolled zinc, tables, methods of testing, physical properties, etc.

Hytempite in the Foundry.—Bulletin setting forth the advantages of this metal for refractory linings. Quigley Furnace Specialties Co., Inc., 26 Cortlandt St., New York, N. Y.

Published by the same firm. "Hytempite in the Power Plant." Sets forth uses of this product for boiler furnace. Chart showing how brick and tile should be laid, fire brick masonry, and much practical and scientific information.

Brass Facts.—Booklet which deals with the characteristics of copper alloys—especially brass. Scovill Mfg. Co., Waterbury, Conn.

Nichrome and other Alloys.—Book R-28 prepared especially to assist those responsible for the proper selection of alloys used in manufacturing processes. Much technical data. 72 pp. Driver-Harris Co., Harrison, N. J.

Choosing A High Temperature Cement.—Booklet containing helpful information for those interested in fire brick construction and maintenance. Illustrated. Technical data, suggested applications. General Refractories Co., 106 South 16th Street, Philadelphia, Pa.

Everything for Mine and Industrial Safety.—Catalog No. 3, third edition. Complete catalog covering mine and industrial safety appliances. Indexed. 136 pp. Mine Safety Appliances Co., Braddock Ave. & Thomas Boulevard, Pittsburgh, Pa.

Laboratory Equipment Catalog.—Looseleaf catalog of laboratory equipment and appliances. Laboratory Construction Co., Kansas City, Mo.

The Catalog of Industrial Thermometers.—No. 625-A. A handsome condensed catalog covering complete line of thermometers for industrial uses. C. J. Tagliabue Mfg. Co., 18 Thirty Third St., Brooklyn, N. Y.

Published by the same firm, "The Automatic Controller Catalog No. 900-A," covering automatic controllers for temperature, pressure, humidity time, condensation and liquid level. "Mono Catalog No. 942," covering improved gas analysis indicator-recorder electrically operated, absorption type. "Laboratory Thermometers and Hydrometers," Catalog No. 417-B describes complete line of extreme precision thermometers. Standard and special grade thermometers.

The Manufacture of Tam Opax.—Photographic story of the various steps in the process of making Tam-Opax—the ultimate opacifier. The Titanium Alloy Mfg. Co., 6007 Euclid Ave., Cleveland, Ohio.

Locomotive Parts of Strong Aluminum Alloys.—Interesting little booklet on the subject. Aluminum Co. of America, New Haven, Conn.

Published by the same firm. "Aluminum in the Chemical Industries." Very interesting brochure on the subject. Illustrated.

Lawtone Refractory Facts.—Contains guaranteed reports of certain facts derived from practical operating experience on boiler settings, elec. melting furnaces, etc. Illustrated. Jonathan Bartley Crucible Co., Trenton, N. J.

Industrial Furnaces.—Catalog No. 12. Interesting booklet containing full information and many illustrations on this type of furnace. The Strong, Carlisle & Hammond Co., 326 Frankfort Ave., Cleveland, Ohio.

Norton Refractory Materials and Their Uses.—Interesting booklet on the application and uses of fused alumina (Alumdum) silicon carbide (Crystolon), fused magnesia and mullite—products of the Norton electric furnace plants. Illustrated. Norton Co., Worcester, Mass.

Published by the same firm, "Character and Uses of Norton Products." Companion book to the above.

Satisfactory Service for Over 70 Years.—Leaflet illustrating and describing the Evans-Howard Fire Brick. Evans & Howard Fire Brick Co., St. Louis, Mo.

The Story of Copper and Its Alloys.—Interesting reprint on this subject. Illustrated. Copper and Brass Research Association, 25 Broadway, New York, N. Y

Chromium Plate.—Bulletins Nos. 1 and 2 illustrate and describe this product for various uses. United Chromium, Inc., 51 East 42nd St., New York, N. Y.

Jessop's Steel Users Reference Book.—Valuable data set forth for the metallurgist. William Jessop & Sons, Inc., 121 Varick St., New York, N. Y.

Published by the same firm, "Jessop's Genuine Sheffield Steels." Handy booklet on this subject.

An Achievement in the Pyrometer Field.—Interesting leaflet on this subject. Thwing Instrument Co., 3339 Lancaster Ave., Philadelphia, Pa.

Nitralloy.—This 32-page booklet is devoted to the nitriding process and the special analysis steels for use in this process. It contains chapters on the following: Nitralloy and the Nitriding Process; The Analyses of Nitralloy; The Physical Properties of Nitralloy; The Operations Prior to Nitriding; The Nitriding Process; The Operations after Nitriding; The Properties of the Nitrided Casel. Ludlum Steel Co., Watervliet, N. Y.

Wrought Iron.—"A New Day in the Age of Iron" is the title of a booklet on Byers New Process (Aston Patents) for Making Wrought Iron. A. M. Byers Company, Pittsburgh, Pa.

Industrial Ovens.—Looseleaf folder containing Sections A, B & C. Full nformation on Japanning, low temperature enameling, lacquering, baking armatures and insulating varnishes, low temperature heat treating, drying processes. Also totally enclosed and recirculating injector burners, ribbon, tip and drilled pipe burners, thermostatic control as well as core ovens. Much valuable data. Profusely illustrated and described. The Crawford Oven Company, New Haven, Conn.

Fleming Combustion Apparatus.—Leaflet illustrating and describing this apparatus. Price list. Eimer & Amend, 3rd Ave. & 18th St., New York, N. Y.

"Industrial" Welded Chromium Iron and Nickel Chrome Alloys.—Booklet illustrating and describing "Industrial" production welding in stainless chrome irons, chrome nickel and other special alloys. Industrial Welded Products Co., 1054 Grand Central Terminal Bldg., New York, N. Y.

The Seal of Approval.—Contains bulletins covering the subject of heat resisting alloy containers for carburizing and annealing operations, cyanide pots, lead pots and kindred equipment. General Alloys Company, 405 West 1st Street, Boston, Mass.

Stainless in the Home.—Booklet setting forth the uses of stainless metals in the home. Illustrated. The American Stainless Steel Co., Commonwealth Bldg., Pittsburgh, Pa.

The A. B. C. of Hydrogen Ion Control.—5th Edition. A discussion of the meaning of Hydrogen Ion concentration and pH values in simple language by W. A. Taylor, Ph.D., LaMotte Chemical Products Co., Baltimore, Md.

Wilson Welding Machines and Arc Welding Wire.—Looseleaf booklet containing data on this subject. Illustrations, tables, specifications. Wilson Welder & Metals Co., Inc., Wilson Building, Hoboken, N. J.

A Metallurgical Study of the Steel Base as Related to Galvanizing by G. A. White, Metallurgical Engineer. Vol. No. 1 of a series on the manufacture of sheet steel. The Matthews-Northrup Works, Buffalo, N. Y.

Ferro-Carbon-Titanium in Steel Making.—Very valuable and interesting treatise on this subject. Illustrated. The Titanium Alloy Mfg. Co., Niagara Falls, N. Y.

Published by the same firm "Ferro Carbon-Titanium" which sets forth Titanium-Treatment of rail steel.

Chapman Products.—Illustrating and describing complete automatic gas producers, semi-automatic gas producers, complete gas producer plants with flue systems, coal and ash handling equipment, automatic feed agitators, automatic feeds, soot blowers. The Chapman Engineering Co., Mount Vernon, Ohio.

Published by the same firm, Bulletin No. 12, "Floating Agitator Producers." Describes this type of equipment fully. "Recuperative Furnaces," bulletin describing recuperative, reheating furnaces. "Annealing and Normalizing Furnaces," bulletin describing equipment for handling steel castings, malleable castings, iron castings, sheet and tin plate, cold rolled and cold drawn strips, tubes, pipe, bars, wire and other miscellaneous material.